A23

The Kent Incorporated Society for Promoting Experiments in Horticulture

ANNUAL REPORT

(TWENTY-SEVENTH YEAR)

1939

EAST MALLING RESEARCH STATION

Near MAIDSTONE

KENT

IMPERIAL MYCOLOGICAL INSTITUTE
20 SEP 1940

1st January, 1939 to 31st December, 1939

Free to Associate Members
Price to Non-Members :—
5/- post free
Great Britain only

Published
August, 1940

THE KENT INCORPORATED SOCIETY
FOR PROMOTING EXPERIMENTS IN
HORTICULTURE

ANNUAL REPORT

(TWENTY-SEVENTH YEAR)

1939

EAST MALLING
RESEARCH STATION

Near MAIDSTONE

KENT

1st January, 1939, to 31st December, 1939

Published August, 1940

PRINTED IN GREAT BRITAIN BY HEADLEY BROTHERS
109 KINGSWAY, LONDON, W.C.2 ; AND ASHFORD, KENT

CONTENTS

	PAGE
Governing Members of the Society	5
Members of the Executive Committee	6
Staff	7
Editorial	9
An Appreciation. Percy Manwaring, J.P.	11

Section I

THE EXPERIMENTAL FARM

Present Acreage	13
Experimental Orchards—Top Fruits	13
Small Fruits	15
Experimental Nurseries	16
Hops	16
Laboratory Field Trials	16
Bradbourne Land	17
Routine Spraying Programme	17

Section II

GENERAL REVIEW OF RESEARCH WORK, WITH LISTS OF PAPERS PUBLISHED DURING THE YEAR

I.	Pomology	20
II.	Statistics and Records	24
III.	Plant Physiology	25
IV.	Biochemistry	27
V.	Plant Pathology, Mycology and Bacteriology	28
VI.	Entomology	30
VII.	Insecticides and Fungicides	32
VIII.	Hops	34
IX.	Technical Section	36

Section III

RESEARCH REPORTS

Pomology

The Present Status of Research in Rootstock Plants and the Use of Rootstock Plants. R. G. Hatton .. 37

A Résumé of the Cherry Rootstock Investigations. N. H. Grubb .. 41

PAGE

Apple Rootstocks Immune from Woolly Aphis. II. The Testing in the Nursery of New Seedling Immunes. H. M. TYDEMAN 44

Apple Rootstocks Immune from Woolly Aphis. III. The Influence of four New Seedling Immunes on Lane's Prince Albert. H. M. TYDEMAN 46

Weather Conditions during 1939. H. C. CHAPELOW and H. M. TYDEMAN 48

BIOCHEMISTRY

Diagnosis of Mineral Deficiencies and Excesses by Systematic Leaf Injection and Analysis. W. A. ROACH 51

MYCOLOGY AND BACTERIOLOGY

Notes on Plant Diseases in 1939. H. WORMALD and R. V. HARRIS 58

The Angular Leaf Spot of Apple Trees. H. WORMALD 63

Review of Research on Strawberry Virus Diseases, 1932-1939. R. V. HARRIS and M. E. KING 66

A Review of Research on Cane Spot of Loganberry and Phenomenal Berry. R. V. HARRIS, A. B. BEAKBANE and M. H. MOORE 68

ENTOMOLOGY

Notes on some Interesting Insects Observed in 1939. A. M. MASSEE 70

Dipping of Strawberry Runners before Planting. A. M. MASSEE and R. M. GREENSLADE 73

INSECTICIDES AND FUNGICIDES

A Brief Review of Research Work at East Malling on the Control of Apple Scab. M. H. MOORE 75

HOPS

The Effect of Various Cultural Treatments on the Cropping of Hops. F. H. BEARD .. 76

Section IV

BULLETINS FOR FRUITGROWERS

POMOLOGY

Plum Growing in the Light of Recent Research. N. B. BAGENAL 79

Studies in Nursery Technique. The Production of Double-worked Pear Trees. R. J. GARNER and D. H. HAMMOND 84

BIOCHEMISTRY

The Study of Mineral Deficiencies and Excesses by Spectrochemical Methods. S. G. THOMPSON 86

INDEX 88

GOVERNING MEMBERS OF THE SOCIETY

Appointed by the Ministry of Agriculture:

Sir Frederick W. Keeble, Kt., C.B.E., D.Sc., F.R.S., Cedron House, Fowey, Cornwall.

Appointed by the Kent County Council:

Ed. Hardy, Esq., J.P., Boughton Court, Ashford, Kent.
Lt.-Col. Sir Albert Stern, K.B.E., C.M.G., Barham Court, Maidstone, Kent.
W. J. Thomas, Esq., Brownings, Rodmersham, Kent.

Appointed by the Surrey County Council:

S. S. Boorman, Esq., Heath Farm, Send, Woking, Surrey.

Appointed by the East Sussex County Council:

E. S. Attrell, Esq., Warren Fruit Farm, North Common, Chailey, Sussex.

Appointed by the West Sussex County Council:

Gen. Sir Ivor Maxse, K.C.B., C.V.O., D.S.O., F.R.G.S., Little Bognor, Fittleworth, Sussex.

Appointed by the Council of the Senate of the University of Cambridge:

D. Boyes, Esq., M.A., School of Agriculture, Cambridge.

Appointed by the Senate of the University of London:

Professor Wm. Brown, D.Sc., F.R.S., 93 Church Road, Hanwell, London, W.7.

Appointed by the University of Bristol:

Professor B. T. P. Barker, M.A., The Research Station, Long Ashton, near Bristol.

Appointed by the Governing Body of the Imperial College of Science and Technology:

Professor V. H. Blackman, Sc.D., F.R.S., Imperial College, South Kensington, London, S.W.7.

Appointed by the Council of the Royal Society:

Professor E. J. Salisbury, C.B.E., D.Sc., F.R.S., University College, Gower Street, London, W.C.1.

Appointed by the Governors of the South-Eastern Agricultural College, Wye:

A. Amos, Esq., M.A., Spring Grove Farm, Wye, Kent.
R. M. Wilson, Esq., B.Sc.Agric., South-Eastern Agricultural College, Wye, Kent.

Appointed by the Research and Advisory Committee of the South-Eastern Agricultural College, Wye:

S. G. Jary, Esq., B.A., Dip.Agric.(Cantab.), South-Eastern Agricultural College, Wye, Kent.

Appointed by the Governors of John Innes Horticultural Institution:

Sir Daniel Hall, K.C.B., M.A., D.Sc., LL.D., F.R.S., John Innes Horticultural Institute, Merton, Surrey.

Appointed by the Council of the Royal Horticultural Society:

E. A. Bunyard, Esq., F.L.S., The Royal Nurseries, The Broadway, Maidstone, Kent. (*Deceased November*, 1939).
F. A. Secrett, Esq., F.L.S., V.M.H., Bell Farm, Felcott Road, Walton-on-Thames, Surrey. (*Appointed November*, 1939).

Appointed by the Council of the Institute of Brewing:

Colonel J. H. Porter, D.S.O., The Newcastle Breweries, Ltd., Haymarket, Newcastle-on-Tyne, 2.

Appointed by the Research Fund Committee of the Institute of Brewing:

G. T. Cook, Esq., Queen's Avenue, Maidstone, Kent.

Appointed by the National Farmers' Union (Central Council, London):

J. S. Chivers, Esq., Messrs. Chivers & Sons, Ltd., Histon, Cambridge.
J. E. Sandall, Esq., Beechwood, Clarkson Avenue, Wisbech, Cambs.

Appointed by the National Farmers' Union (Kent Branch):

Alfred Day, Esq., J.P., Great Tong Farm, Headcorn, Kent.
S. R. Dixon, Esq., Cambridge, Teynham, Sittingbourne, Kent.
W. T. Edmonds, Esq., Allington Farm, Maidstone, Kent.
E. Bruce Gibson, Esq., Lumbersland, Birchwood, Wilmington, Dartford, Kent.
Sir Amberson B. Marten, Kt., M.A., LL.D., Gedges, Matfield, Paddock Wood, Kent.
A. T. Miller, Esq., Wested Farm, Swanley, Kent.
D. J. Moor, Esq., Nichol Farm, Teynham, Sittingbourne, Kent.
S. W. Mount, Esq., Hode Farm, Patrixbourne, Canterbury, Kent.
T. Neame, Esq., The Offices, Macknade, Faversham, Kent.
J. A. Raynham, Esq., Dairy Farm, Marden, Kent.
J. M. Robertson, Esq., Beluncle, Hoo, Rochester, Kent.
J. F. Towner, Esq., Salts Farm, Loose, near Maidstone, Kent.

Appointed by the Council of the Horticultural Trades' Association:

L. J. Cook, Esq., 7 Drapers Road, Enfield, Middlesex.

Appointed by the Associate Members of East Malling Research Station:

Stuart Macdonald, Esq., Little Baddow Hall, near Chelmsford, Essex.
Captain R. Wellington, M.C., Worth, Hele, Bradninch, S.O., Devon.

Appointed under Article 7, by the Society in General Meeting:

The Most Hon. The Marquis Camden, G.C.V.O., T.D., J.P., Bayham Abbey, Lamberhurst, Kent.
Percy Manwaring, Esq., 4 Keppelstone, King Edward's Parade, Eastbourne, Sussex.

MEMBERS OF THE EXECUTIVE COMMITTEE

(Governing Members elected at the General Meeting, June, 1939)

Arthur Amos, Esq., M.A.
Professor B. T. P. Barker, M.A.
Professor V. H. Blackman, Sc.D., F.R.S. (Vice-Chairman).
Professor Wm. Brown, D.Sc., F.R.S.
J. S. Chivers, Esq.
G. T. Cook, Esq.
L. J. Cook, Esq.
Alfred Day, Esq., J.P.
W. T. Edmonds, Esq.
E. Bruce Gibson, Esq.
Sir Daniel Hall, K.C.B., M.A., D.Sc., LL.D., F.R.S.
S. W. Mount, Esq. (Chairman).
T. Neame, Esq. (Chairman, Finance Sub-Committee).
J. M. Robertson, Esq.
Professor E. J. Salisbury, C.B.E., D.Sc., F.R.S.
J. E. Sandall, Esq.
Lt.-Col. Sir Albert Stern, K.B.E., C.M.G.
W. J. Thomas, Esq.
Capt. R. Wellington, M.C.

Co-opted Members:

H. V. Taylor, Esq., O.B.E., D.Sc.(Lond.), A.R.C.S., Horticultural Commissioner, Ministry of Agriculture.
W. Rogers, Esq., Court Lodge, Horton Kirby, Kent.

The Director:

R. G. Hatton, Esq., C.B.E., M.A.(Oxon), D.Sc.(Lond.), V.M.H.

The Representative of Staff Council:

M. H. Moore, Esq., Dip.Hort.Sci.(Reading).

STAFF

Director : Ronald G. Hatton, C.B.E., M.A.(Oxon.), D.Sc.Hort.(Lond.), V.M.H.

Assistant Director : H. Wormald, D.Sc.(Lond.), A.R.C.S., D.I.C. (*Resigned October*, 1939.)

Assistant to Director : T. N. Hoblyn, Hort.Dip.(Wye). (*Appointed October*, 1939.)

Technical Officer : N. B. Bagenal, B.A.(Cantab.).

Assistant : B. F. G. Levy, B.A.(Cantab.), Hort.Cert.(Reading).
H. B. S. Montgomery, B.A.(Dublin), Ph.D.(Lond.), D.I.C. (*Part time.*)

Pomology : R. G. Hatton,* C.B.E., M.A.(Oxon.), D.Sc.(Lond.), V.M.H.
N. H. Grubb, M.S.A.(Cornell).
W. S. Rogers, M.A., Ph.D.(Lond.), Dip.Hort.(Cantab.).
J. Amos, N.D.H.
W. A. Bane, B.Sc.Hort.(Reading). (*Resigned August*, 1939.)
Miss A. B. Beakbane, B.Sc.Hort.(Lond.), N.D.H.
Miss C. P. Field, B.Sc.Hort.(Reading).
Miss E. C. Thompson.

Lab. and Field Assistants : C. H. W. Slater. Miss F. M. Hodge.
Miss E. C. M. Ashdown. Miss M. Stevenson.
Mrs. Bingham. Miss J. L. Tomsett.

Plant Breeding : H. M. Tydeman.

Propagation : R. J. Garner, N.D.H., Dip.Hort.Sci.(Reading).
D. H. Hammond.

Marketing Investigations : A. C. Painter.

Hops : F. H. Beard, Hort.Dip.(Wye).

Walnuts : A. W. Witt, N.D.H. (*Consultant*).

Statistics : T. N. Hoblyn,* Hort.Dip.(Wye).
S. C. Pearce, B.Sc.(Lond.).
Miss J. S. Plackett.
Lab. Assistant : W. A. J. Bourne.

Plant Physiology : M. C. Vyvyan,* M.A. (Cantab.).
H. L. Pearse, Ph.D.(Lond.), A.R.C.S., D.I.C., of the Imperial College of Science and Technology. (*Resigned October*, 1939.)
D. W. Goodall, B.Sc., D.I.C., of the Imperial College of Science and Technology. (*Appointed September*, 1939.)
Lab. Assistant : G. F. Trowel.

Bio-Chemistry : W. A. Roach,* D.Sc.(Lond.), A.R.C.S., D.I.C., A.I.C.
J. K. Eaton, B.Sc.(Wales), M.Sc.Tech.(Manc.).
Lab. Assistant : R. Blunden.

Mycology and Bacteriology : H. Wormald,* D.Sc.(Lond.), A.R.C.S., D.I.C.
R. V. Harris, B.Sc.(Lond.), A.R.C.S., D.I.C.
H. B. S. Montgomery, B.A.(Dublin), Ph.D.(Lond.), D.I.C. (*Part time.*)
Miss M. E. King, B.A.(Cantab.), *Special Assistant, Virus Diseases.*
W. G. Keyworth, B.Sc., A.R.C.S., *Special Assistant, Hop Diseases.*
D. L. G. Davies, B.Sc., Ph.D.(Bristol), *Special Assistant, Hop Diseases.*

Entomology : A. M. Massee,* D.Sc.(Lond.), F.R.E.S.
R. M. Greenslade, B.Sc., A.R.C.S.
G. H. L. Dicker, B.Sc., A.R.C.S., Ph.D.(Lond.), *Special Assistant, Pests of Raspberry, Blackberry and Loganberry.* (*Resigned December*, 1939.)
Lab. Assistant : F. Cronk.

* Recognized Teacher of the University of London.

Insecticides and Fungicides :

Chemistry : H. Shaw, M.Sc.Tech., Ph.D.(Manc.).
Lab. Assistant : R. N. Pierce. (*Resigned October*, 1939.)

Entomology : W. Steer, B.A. (Cantab.).
R. G. Gambrill, *Recorder.*

Mycology : M. H. Moore, Dip.Hort.Sci.(Reading).
Lab. Assistant : D. Bates. (*Appointed April*, 1939.)

Meteorological Investigations : C. E. Cornford, B.Sc., A.R.C.S.

Laboratory Assistant G. P. R. Mount. (*Appointed May*, 1939.)

Guide Demonstrator and Exhibitions Officer : H. C. Chapelow, *Meteorological Records.* (*Retired September*, 1939.)

Photographer : Miss K. E. Cornford. (*Resigned June*, 1939.)
W. F. Bond. (*Appointed June*, 1939.)

Lab. Stewards : Miss K. E. Cornford. (*Resigned June*, 1939.)
R. G. Gambrill.

Advisory Officers in Commercial Fruit Growing to the Kent Education Committee stationed at East Malling Research Station : W. G. Kent, N.D.H., and C. R. Thompson.

ADMINISTRATION.

Secretary : C. T. Royle.

Book-keeper : P. R. Wood.

Director's Personal Secretary : Miss L. E. Alexander.

Clerical Staff : Miss J. M. Coy, Miss J. M. Crayford, Miss G. O. Ardagh, Miss H. D. Gilmore, Miss J. D. Martin, Miss M. I. Sunnuck and Miss J. Banks.

VISITORS.

The headquarters of the Technical and Advisory Section have been moved to Bradbourne, Larkfield, and visitors are asked to call there before going to the Station and not to proceed direct to the Laboratories at East Malling.

All *correspondence* should still be addressed to East Malling Research Station, near Maidstone, Kent.

Visits may be paid on any weekday, *by appointment* if possible (Saturday afternoon under exceptional circumstances only).

Passenger Station : East Malling Halt (Southern Railway). *Goods Station :* Aylesford (Southern Railway).

Bus Services : From Maidstone by the Maidstone and District Motor Services Limited, every 20 minutes from Maidstone to Larkfield. From London the coaches call at East Malling and Larkfield on certain inward and outward journeys.

Visitors coming by road should take the turning to East Malling Village, opposite the Bull Hotel, Larkfield, on the main London-Maidstone Road. The entrance gate to Bradbourne is on the left approximately 100 yards down the road.

Telephone : Aylesford 7294 (2 lines). *Telegrams :* Research, East Malling

---

THE IMPERIAL BUREAU OF HORTICULTURE AND PLANTATION CROPS

Accommodated at Bradbourne, the Administrative Headquarters of the East Malling Research Station.

STAFF.

Director : Ronald G. Hatton, C.B.E., M.A.(Oxon), D.Sc.(Lond.), V.M.H.

Deputy Director : D. Akenhead, M.A.(Oxon), B.Sc.Agric.(Lond.).

Assistants : G. St. Clair Feilden, B.A.(Oxon).
B. Von Heiseler, F.I.L.

Clerical Staff : Miss M. B. Rogers, Miss M. M. Durling and Miss B. G. Goodwin.

Telephone : Aylesford 7294 (2 lines).

EDITORIAL

THE Annual Report for 1939 has been arranged along the same general lines as in former years, and certain improvements introduced in 1938 have been retained. The fuller list of contents, the index, and the clearer setting out of the summaries of publications during the year, all received favourable comment.

It has, however, been found necessary, as with other publications, to reduce the size this year. This has been attained in several ways. Instead of setting out in full and reporting progress on each individual item of our research programme, the heads of each Section have been asked to contribute briefly a more general review in Section II. In these reviews the work carried out in the year is summarized so as to indicate the stage reached since its inception, and an outline of the future development of many of the projects is given. The whole programme has been discussed and revised during the past winter but the publication of these details in full is being held over until happier times. Again, in the same Section, while the titles of all published papers are given, only summaries of those which record definite stages reached in the Station's investigations, and which are not readily available to our Members, are included.

The papers selected for publication in Section III have largely been selected this year for their immediate practical bias, while the more detailed theoretical papers have been held over for the present. Indeed Sections II, III and IV form a consecutive whole and we hope that our fruitgrower members may find time and justification for reading all three carefully.

The unavoidable delay in the publication of this Report has enabled us for the first time to present in Section I the horticultural year of the Experimental Farm and not the Station's Financial Year (1st October-30th September) as has previously been necessary. We hope this will make the present chronicle of the Farm more interesting to our Members.

For the first time, too, all the investigations upon Hops are brought together in a single Section (No. VIII) instead of being scattered about in the various Sections which deal with different aspects of the work. It will thus be easier for hopgrowers and brewers to keep in touch with developments.

The general editorship of this Report has once again been undertaken by Dr. Wormald, but the heads of Sections are responsible for Sectional Reports.

R. G. HATTON.

June 1940.

PERCY MANWARING, J.P.
Chairman of East Malling Research Station 1919-36

Photograph of the presentation portrait painted by Murray Urquhart, R.B.A.

AN APPRECIATION

PERCY MANWARING, J.P., Chairman, E.M.R.S. 1919-36

PERCY MANWARING slept peacefully away on 15th April, 1940, and *The Times* concisely summarized his public service in the following words :

" Percy Manwaring, formerly of Knowle Paddock, Sevenoaks, died from pneumonia in Sussex on Monday at the age of 76. He was the youngest son of the late Mr. T. Manwaring, of Marle Place, Brenchley, Kent, in which county the family had been established for many generations. He inherited the family skill as fruit and hop growers and farmed a large acreage of fruit and hops. He was a member of the Kent County Council from 1907 to 1928, a county alderman during the last seven of those years, and was chairman of the Agricultural Education Committee from 1922 to 1928. Between 1922 and 1938 he was a magistrate of the Cranbrook and Sevenoaks divisions. But his main thought was for agriculture, and in February, 1918, his fellow farmers elected him chairman of the Kent branch of the National Farmers' Union, and he was re-elected for five years in succession. He was a governor of the South-Eastern Agricultural College, Wye, from 1921 to 1930. When Wye College Fruit Experiment Station was incorporated, as East Malling Research Station, into an independent society for horticultural research in 1919, he became the first chairman of the institute and guided its activities for sixteen years."

While it is a temptation to amplify these details, it seems more fitting in this Annual Report to give a more intimate picture of our late Chairman as he appeared to those of us who were privileged to be closely associated with him in that capacity.

My first introduction to Percy Manwaring was in the autumn of 1912, when as field assistant to Professor Salmon, I met him in one of those incredible old wealden orchards which are now a thing of the past. I say incredible because I remember so vividly Percy Manwaring's pride in showing us a marvellously well-grown yet exquisitely coloured crop of Worcesters top-worked upon some gnarled and aged stems of, I believe, Manx Codlin.

Professor Salmon had been doing some pioneering experiments with Bordeaux mixture thereon and we had come to inspect the results. It was also the time when Wye College was advocating the adoption of box packing, and, as a rather timid apostle, I ventured the remark that such a sample would be worthy of such treatment. " All right, young feller," was the prompt reply, " you must come along again when picking starts and give our packers a lesson." I remember later, in an overcrowded old barn, trying to demonstrate to an assemblage of old wealden dames the new " cheek to eye " diagonal pack, Percy Manwaring standing by with that mischievous twinkle in his eye, for which all his friends learned to look. My first impression was that of a man steeped in all the traditional lore of his fruitgrowing ancestors, forcing good apples to grow in out-of-date orchards, yet looking open-mindedly, even encouragingly, at the new movement to apply science to horticulture. But that was not my only impression, for I had been shown hospitality in that lovely setting at Plovers, Horsmonden, and then, as a stranger in the garden of England, had been transported to this and that vantage point to survey the fairest prospects of which he never tired.

Although it was some seven years before we became so closely associated in the work at East Malling, that early introduction had ensured his interest and support, and despite the pressure of work which the Great War brought to all of those engaged in Food Production, Percy Manwaring had time to keep an eye on the work of the Wye College Fruit Experiment Station at East Malling which had already developed too far to be permitted to close down altogether for the " duration ".

This was indeed fortunate for, when in April, 1919, Lord Ernle, as Minister of Agriculture, addressed fruitgrowers at Maidstone and offered more substantial Government support for horticultural research in Kent, if growers on their part would give more material assistance, it was Percy Manwaring who accepted the challenge to arouse local interest and raise the necessary funds. He was then Chairman of the Kent Branch of the National Farmers' Union to which post he was re-elected five times in succession, as a tribute to his devoted and efficient service.

It was indicative of his whole point of view that he should plead both causes so insistently at one and the same time. When he accepted the Chairmanship of the Kent Farmers' Union in February, 1918, he clearly and fearlessly stated the aims which he had in view. Whilst his thoughts and energies would be directed towards the revival of prosperity in English Agriculture, and a strong and united Union was one great means to that end, the prosperity he visualized was to benefit all the partners in Agriculture alike—landlord, farmer and labourer, and was not to be self-centred. Whilst he wanted, through the Union, to bring pressure to bear on Government to give Agriculture fair treatment, he did not place all his trust in politicians and intended to " seek by scientific study to obtain the very best methods of production, that the land might be made to give the very best, that the food of this country might be secure ". On such a platform, he feared no criticism and worked unremittingly in the dual yet common cause of the N.F.U. and of Research.

In 1919 he accepted the Chairmanship of the newly constituted " Kent Incorporated Society for Promoting Experiments in Horticulture ", which took over the assets and liabilities of the Wye College Fruit Experiment Station. The "N.F.U. Building" (1921)—a Physiology Laboratory, Library and Offices—and Egham Field (an additional 40 acres) were the first fruits of his appeal to the industry. When, as a result of the demands of fruitgrowers, the Station grew more rapidly in its activities and needs than did enthusiasm and material support at Headquarters, Percy Manwaring, confident of the ultimate success of his cherished scheme, faced the serious financial situation and encouraged the staff to go forward. His faith and persistence ultimately had their reward, and the Ministry of Agriculture placed the Institution on a more sound financial footing.

By 1925, the Station had again outgrown its land and buildings, and it was Percy Manwaring who conceived the idea of applying to the Hop Control Board, at its winding up, for some of the surplus remaining in its hands from the sale of confiscated hops. The " Manwaring Building " (1927) and Church Fields (an additional 23 acres)—incidentally the first hard-won portion of the Bradbourne estate—stand as a memorial to his energy and persuasiveness.

Hard on this development came the interest of the Imperial Agricultural Research Conference in East Malling's work. Instead of being suspicious of these wider claims upon the Institute, Percy Manwaring, through the Central Council of the N.F.U., formally drew the attention of the Empire Marketing Board to the needs and potentialities of East Malling. He appreciated the value of an interchange of scientific information and of a pooling of resources. In a similar broadminded spirit, he welcomed the Institute's recognition by the University of London and the formation of a Staff Council which should elect a representative on to the Governing Body and Executive Committee of the Institute. In this way he saw a remarkably rapid increase in the completion of the staff team and its equipment, and in 1930 he welcomed Lord Addison, as Minister of Agriculture, to open the new " E.M.B. Building " with its Pomological and Statistical Sections and a more adequate Library.

Instead of discouraging the natural expansion of the Institute, Percy Manwaring tried to provide for its future needs by building up an Associate Membership Scheme and an Endowment for future developments. His enthusiasm for the Institute knew no bounds, and he talked " Research " and " East Malling " to everyone likely to be interested on every possible occasion. Although these schemes were constantly hindered by financial depressions and political crises, he persevered and took a personal interest in the enrolment of each new Member and the reception of every donation. While he always hoped one day to find a " fairy godmother " to endow the work in which he had such great faith, he expressed his satisfaction that the bulk of the support came individually from farmers and their friends. No wonder that he took great pride in the Station's twenty-first birthday celebrations when he welcomed the present King—then Duke of York—and handed to him the list of donors to the Endowment Fund.

Although he had to keep a close eye on his own farms and was immersed in the business of the National Farmers' Union and in County affairs, rarely a week passed without his paying an informal visit to the Research Station. Thus he came to know well not only the from day to day problems of the Institute, but also the individual members of staff. To them he became a personal friend as well as an accessible Chairman, joining in their games and other social activities.

Although his failing health caused him to resign the Chairmanship of the Executive Committee, after sixteen years' service, in 1936, "in order to give the younger men a chance", as he put it, I shall always remember his last official visit to the Station in December 1938. As soon as it was known that Bradbourne was to come upon the market, Mr. Spencer Mount, who succeeded him as Chairman, and Mr. Thomas Neame, Chairman of Finance, asked Percy Manwaring to come and give his advice on the proposal to acquire the estate in order to safeguard the future needs of the Station for land and buildings for all time. Both recalling the history of past difficulties which had been encountered in extending the Research Station piecemeal and in providing adequate accommodation for its expanding activities, and also visualizing the possibilities which such a step would open up for the Institute for which he had so devotedly laboured, he gave the scheme his full encouragement though he was not destined to see it brought to fruition.

There now hangs in the Board Room at Bradbourne the oil painting of him by Murray Urquhart (see reproduction on frontispiece) which was part of the presentation made by our Associate Members in grateful recognition of his single-minded service on behalf of the Fruit and Hop growing community.

For nearly twenty years I had the privilege of his wise guidance and of his personal friendship throughout this most crucial period of our Research Station's development. Hence I can speak with intimate knowledge of his influence upon the progress of scientific fruitgrowing. His intense conviction that science was the true keystone to the industry combined with his gift of convincing his fellow fruitgrowers of this by his patent sincerity and inexhaustible good humour, made him the ideal advocate of a cause for which he pleaded so persistently and so successfully. It is in fact true to say that Percy Manwaring made possible that whole-hearted collaboration between the investigator and the fruitgrower which exists to-day.

R.G.H.

Section I

THE EXPERIMENTAL FARM

By R. G. HATTON and T. N. HOBLYN,
with Section on Spraying by M. H. MOORE

It is now ten years since we started this Section of our Annual Report. It is hardly necessary to reiterate that it is not intended to present an account of a model fruit farm run on the most up-to-date and economical lines ; it is rather an account of some of the most interesting happenings on the experimental farm, where of necessity many of the operations are far more laborious and expensive. It is possible, however, to give certain exact records of spraying, yields, and the prices obtained for produce marketed, from which interesting deductions can be drawn.

Present Acreage.—Up to October 1939 the land owned or occupied by the Institute was approximately 160 acres, of which some 40 acres are farmed on behalf of the Trustees of our Development Fund. It should be remembered that the amenities of an experimental farm take a much greater toll of land than on a commercial farm. Further, the comparatively small size of experimental plantings entails a disproportionate amount of headlands. The central road through the Station alone occupies 2 acres and there are similar subsidiary roads at either side of it. Thus just over 10 acres are occupied by the laboratories, experimental greenhouses, dwellings, farm buildings, packing sheds, their surrounds and roads. Whilst from the farming point of view this area is entirely unproductive, its maintenance falls on the farm staff.

It is intended this year, instead of dealing with the farm field by field, to give a bird's-eye view of the main experimental crops to which it is now planted, together with any particularly interesting details relating thereto in the current season.

Below will be found a summary of how the land is at present occupied :

Buildings, roads and woodland (3 ac.)	13·15 acres
Experimental orchards :	
Top Fruits	79·55 ,,
Small Fruits	17·50 ,,
Experimental Nurseries	22·45 ,,
Experimental Hop Gardens	9·25 ,,
Laboratory field trials (entirely unproductive)	10·15 ,,
Arboretum and Nursery Plots (recently cleared for food production)	7·95 ,,
	160·00 acres.

The approximate acreages given are based on the actual land occupied at the present time by the different crops. In the interplanted orchards the number of trees or bushes of each sort of fruit determines the acreage allotted thereto. For instance, actually the sweet cherries are spread out over some 14 acres and they will eventually fully occupy that area. At present, however, plums, acid cherries, bush apples on No. IX, and black currants (all planted as fillers) occupy more than half the total space so that 8 of these acres are divided between these crops, and the sweet cherries are shown as occupying only 6 acres.

Experimental Orchards—Top Fruits. Of nearly 80 acres occupied by Top Fruits, 50 acres are devoted to Apples, 14·5 acres to Plums, 8 acres to Cherries and 7 to Pears.

Before discussing the points of interest in the cropping of the individual orchards reference should be made to the meteorological conditions during 1939 detailed on p. 48. After the "off" year which resulted from the late spring frost of 1938, the majority of fruits blossomed heavily. Apart from those seasonal conditions which caused some serious spray damage, both to apples and plums, most fruits set a heavy crop. Apples especially did not quite come up to their early promise, as there was an extremely heavy fruit drop in July, both on Bramley's Seedling and Cox's Orange Pippin, due to some factor as yet unexplained. The main plantation of Victoria plums lost all of its blossom owing to unfavourable weather conditions following petroleum spraying.

Apples.—The principal varieties grown mainly for Rootstock, Pruning, Manurial and Cultural investigations are :

Worcester Pearmain	10·0 acres.
Bramley's Seedling	9·5 ,,
Cox's Orange Pippin	8·0 ,,
Lane's Prince Albert	4·5 ,,
Lord Derby	2·5 ,,
Beauty of Bath	1·5 ,,
Duchess Favourite	1·5 ,,
Barnack Beauty	1·0 ,,
Other mixed varieties	10·5 ,,
Cordons	1·0 ,,
	50·0 acres.

Of the four principal varieties of apple the most regular cropping have been Worcester Pearmain and Lane's Prince Albert. With the exception of the year 1935 both varieties have produced crops annually. In 1939 20-year-old Lane's Prince Albert in a rootstock trial on Great East Field produced about 3½ bushels per tree of exceptionally fine quality fruit. A similar trial of Worcester Pearmain of the same age produced 4 bushels per tree. The fruit from the plantation of Lane's Prince Albert kept very successfully in a " scrubber " gas store at the Ditton Laboratory until January, when its exceptional condition was favourably commented upon in the market.

Bramley's Seedling has been usually extremely biennial in habit and susceptible to damage in years of spring frost. In 1939, following a crop failure due to this cause in the previous season, the trees blossomed heavily. However, owing to the heavy fruit drop, the crop was not the heaviest that the trees have produced. The average yields per tree were about 4 bushels on Kiln Field (25 years old) and 7 bushels on Great East (20 years old).

Cox's Orange Pippin has been very irregular in its crop, but this may partly be due to experimental exigencies and in part to inefficient pollination, a condition which has now been remedied. In 1939 they suffered a fruit drop similar to Bramley's Seedling, particularly in some plantations. The trees in the rootstock trial on Egham Field (17 years old) averaged 2 bushels a tree, which is actually the heaviest crop yet borne on this plot. Of the other varieties, Lord Derby and Grenadier have cropped regularly. Most of the other varieties yielded heavily in 1939.

The 10 acres of " other mixed varieties " includes a two acre plantation of bush trees containing a collection of nearly a hundred varieties now 18 years old. This has now fulfilled its purpose and, since such a heterogeneous plantation is extremely difficult to spray, manure, and harvest under optimum conditions, it is being " top- " and " frame-worked " as rapidly as possible. The scions chosen for this purpose are Cox's Orange Pippin and a few other high quality dessert apples which have cropped well in this trial, and very late blossoming varieties such as Edward VII and Crawley Beauty, with others particularly susceptible to frost damage, such as Bramley's Seedling and Belle de Boskoop for comparison with them. Although the vast majority of the varieties did not prove of economic value under our conditions, the performances of three or four, such as Ribston Pippin and Egremont Russet, justified their continuance and even extension. Perhaps the most suggestive point arising from this orchard has been the heavy crops harvested from many varieties even in frosty years.

Actually from some 45 acres of maturing apple trees (5 acres are as yet only 5 years old) 15,231 bushels were marketed. This is the heaviest crop of apples yet grown, being nearly 1,000 bushels more than the 1936 yield. This is a particularly interesting fact, since at that time the general plant on the farm was round about 15 foot square. During the past few years, and especially in 1938 and 1939, a large percentage of the alternate trees have been removed. Also many mature trees have been frame-worked, both to provide more efficient pollination, when needed, and to replace varieties unsuitable to the general spray schedule. On Kiln Field alone more than 50% of the trees have already been removed and the same applies to the older plots on Great East. The close approximation of the 1936 and 1939 crops suggests that those which remain are rapidly growing in efficiency.

The *gross* returns on this crop were £4,498, or an all over figure of approximately 6s. a bushel *gross*. From this low average price must be taken all the costs of picking, grading, storing, packing and marketing, in addition to the cost of production.

Pears.—There are about 7 acres of pears on the Station. These are mainly situated in three plantations on Egham Field, aged from 12 to 20 years, and interplanted in a plantation of apples on Church Fields where there are 162 fifteen-year-old half-standard Dr. Jules Guyot on clonal free stocks,

with Reine des Poires as a pollinator. This interplanting procedure will never be repeated owing to the impossibility of synchronizing the spraying of apples and pears with success.

In all, twenty varieties are included, of which Conference (1 acre), Dr. Jules Guyot (2 acres), Emile d'Heyst (0·5 acres) and Durondeau (0·5 acre) form the majority. Conference has been the only one to bear regular crops over a period of years, the remainder only cropping heavily in outstanding "pear" years, such as 1934, 1936, and 1939, when the heaviest crop of about 300 bushels to the acre was harvested. Some 2,000 bushels were marketed in all and these averaged a *gross* return of £712, or 7s. a bushel. The total yield would undoubtedly have been higher but for the percentage of less productive varieties such as Doyenne du Comice, Pitmaston Duchess and Beurre Hardy, which were planted to study particularly the reasons for their uncertain cropping. In the past season about 100 unprofitable trees were successfully "frame-worked" to Laxton's Superb and Williams' Bon Chrétien to explore the possibilities of encouraging the growing of these varieties on a larger scale.

Plums.—There are four main plum plantations on the Station, covering an area of about 14·5 acres of which 11·5 acres are in cropping. Two of these, aged 18 and 14 years respectively, are on Egham Field and the main varieties are now Victoria, Czar, Rivers' Early Prolific and Purple Egg. Additional varieties of interest are Warwickshire Drooper, Pershore Egg, Bradley's King damson, Cherry Plum (largely used as windbreak), and Giant Prune. On Church Fields there is a plantation, now 13 years old, which includes Victoria, Cambridge Gage, Pershore Egg, Czar and Cluster Damson. The other plum plantation on Deadman Field includes 3 acres of 9-year-old Giant Prune and 3 acres of 3-year planted Victoria. By far the most regular cropping plum has been Czar, though very heavy crops of Victoria, Giant Prune, Pershore and Purple Egg have been harvested in some seasons. Owing to the recognized over-production of such varieties as Czar and Purple Egg, some 270 of these trees are being frame-worked to high quality dessert sorts, mainly gages, and late ripening varieties, such as Monarch, Warwickshire Drooper and President. Owing to the overcrowding of the oldest plum plantation, some 90 trees of President have had to be grubbed. Though they have been slow to bear and irregular in cropping, these have actually produced the highest yield per tree and the fruit, owing to its late ripening and fine appearance, has invariably sold well.

Despite the spray damage to the Victoria crop referred to elsewhere, some 3,861 halves of all varieties were marketed of which 1,880 came from the 3 acres of Giant Prune on Deadman. The plums had been thinned and were of excellent quality, but only fetched an average *gross* return of 3s. a half-sieve, owing to the conditions prevailing on the market during the plum season.

Cherries.—For reasons already given it is reckoned at the present time that an area of 8 acres is devoted to cherries, of which 6 acres are standards—mostly sweet cherries—and 2 acres are bush acid cherries. Three acres of standards consist of a collection of 160 varieties of sweet and acid cherries, about 2 to 4 trees of each. These vary in age from one to nineteen years old as the collection accumulates, and are being used for purposes of identification and selection. A few of the older trees are now coming into full bearing, but owing to extreme differences in age and variety, the orchard is very difficult to manage. About £100 worth of sweet cherries were sold off this area in 1939. The other three acres include equal numbers of fourteen-year-old Early Rivers, Bigarreau Schrecken and Turk upon different clonal Mazzard rootstocks. These have not yet borne any quantity of fruit, though they have blossomed profusely.

Half an acre is devoted to a solid plant of 17-year-old bush Morellos at 12 feet square, while 1½ acres of Morello, Kentish and Carnation are interplanted among the standards. The last of these varieties has never cropped and the trees are now to be used for experiments in frame-working cherries. The first considerable crop since 1937, about 3½ tons of Morellos and Kentish, was sold in 1939 and fetched a *gross* return of £206.

Small Fruits.—Approximately 17·5 acres are devoted to small fruits for cropping and cultural trials.

Strawberries occupy ten of these acres. Six were planted in October 1938 and the other four in April 1939 to East Malling clonal Royal Sovereigns. The autumn planted ones looked so extremely vigorous that, contrary to our normal practice based on experimental findings, they were not deblossomed. They only bore about six hundredweight per acre, which could hardly compensate for the labour and expenditure involved in strawing, picking and subsequent difficulties in cleaning. Both areas promise well for 1940.

There are 4 acres of 7- and 8-year-old *Black Currants* on Newgates Field, including the main commercial varieties planted at varying distances. In addition, in 1939, there were 4 acres of Wellington XXX interplanted between cherries and plums on Church Fields, most of which have since been grubbed, and a small trial of new seedlings. The total sales amounted to 11 tons which produced a *gross* return of £540.

About an acre is occupied in the testing of new *Raspberry* seedlings, which produced some 2½ tons

of marketed fruit (£107 *gross*). A similar area is devoted to different varieties of *Blackberry* and *Loganberry* which yielded approximately 3 tons (£114 *gross*).

Collections of red currants, gooseberries and raspberries are still maintained and are interplanted in various plantations. The produce therefrom sold for £107 *gross*.

Experimental Nurseries.—Of the remaining 50 acres, some 22·5 are in experimental propagation work. In 1939 11 acres were in permanent rootstock stoolbeds. It was decided in the autumn to reduce this area by nearly 50% owing to the war. Actually weather conditions only allowed the grubbing of some 2 acres. Two further acres were occupied by bedded rootstocks and 2 acres with miscellaneous cuttings, very few of which have been saleable in the past season. The past winter found us with by far the largest nursery of young trees and budded rootstocks which the Station had ever held. Some 50,000 young trees, occupying over 6 acres of ground, were in preparation for further experimental plantings of apples, pears, plums, cherries, peaches and apricots. A decision as to the future of these trees will become imperative in the autumn of 1940. Nearly an acre is occupied with the raising of disease-free raspberry, loganberry and blackberry clones. Several nursery areas, amounting to 2½ acres in all, were cleared during the winter and have been planted to potatoes.

During 1939 we had 5 acres of Royal Sovereign strawberry runner beds, in addition to 2 acres interplanted with young apples mentioned elsewhere. Since the demand at a remunerative price for runners was very poor, this area has been reduced to 2 acres, and the other three planted to potatoes. In 1939 the total sales from these nursery areas amounted to only £2,081, as against £3,217 in the previous season.

Hops.—Nine-and-a-quarter acres are under Hop experiments. Apart from the half-acre of selected Fuggles and a quarter-acre of virus-free Golding varieties, the whole area is occupied with new varieties from the S.E. Agricultural College, Wye. Some 2½ acres of these varieties consist of six selections (including Brewer's Favourite, Quality Hop, and Fillpocket) grown in bulk for large scale brewing tests. They are also used in various cultural investigations relating to cutting, pulling, training, stopping, etc. Five and a half acres are still occupied by 15 hill plots of some 200 new seedlings. These gardens are always in a state of flux, less valuable varieties being grubbed and new ones taking their place. As a result 1½ acres are not at present in full cropping. Despite this, nearly 8 tons, the heaviest crop yet obtained, were picked off the whole area. Some very high individual yields were recorded.

On the whole the weather conditions were favourable. Downy Mildew was not troublesome at any period. A few young hills in the seedling garden suffered rather severely from red spider, but no mature hills were affected. *Botrytis* rot of the cones was fairly general and was worst on seedlings derived from the New Mexican hop. The half acre of OI47 in Church Field garden was so badly affected that it had to be picked before it was mature.

The prices obtained for our growth were substantially higher than in the previous season. A few comparisons are given below :

	1938.			1939.		
	£	s.	d.	£	s.	d.
Fuggle	9	0	0	9	10	0
Brewer's Gold (C9a) ..	10	10	0	11	0	0
Bullion Hop (Q43) ..	10	10	0	11	0	0
Brewer's Favourite (OP21)	9	5	0	9	15	0
Quality Hop (OO63) ..	9	10	0	9	15	0
Fillpocket (Z62)	9	0	0	9	15	0
Early Promise (X35) ..	8	10	0	10	0	0

Despite the large proportion of mixed seedling growths the total price obtained was £1,600. Against this must be set the very heavy costs of picking, weighing, drying and packing separately such a large number of small lots.

Laboratory Field Trials.—Over 10 acres are occupied by small scale intensive plantings of many varied horticultural crops, especially requisitioned by the various research sections. These include the meteorological plot and phenological garden.

In addition to the large scale and experimental nursery work, 3 acres of land have been occupied by intensive nursery trials, designed to evaluate the newer rootstock introductions. These trees are planted very close and are allowed to grow at will so that an idea of vigour and precocity may be obtained quickly. Such plots are very difficult to manage and cannot be expected to yield a productive return.

About 2 acres are at present occupied by the plant breeders in the initial trials of new varieties of top and small fruits. These are rarely harvested as the fruits are left for observation of season and colour characteristics.

Apart from the general facilities on the experimental plots extended to the plant pathologists,

some 3 acres are given over to material reserved for their investigations, while a further 2 acres are occupied by the Physiology, Biochemistry and Pomology Sections for propagation investigations, material for studying spray injury, injection methods, anatomical studies and cover crops.

It will be readily understood that this 10 acres produces no crops of saleable value and of course absorbs an exceptional amount of labour.

Two acres of specimen trees—rootstock varieties and a collection of oriental cherries—have been grubbed and planted to potatoes. It is hoped to re-establish this arboretum later in the shrubberies at Bradbourne. Three acres of woodland have been interplanted with a collection of young walnut varieties.

In the first winter of the war, we have succeeded in grubbing and releasing nearly 8 acres of experimental ground for the growing of food crops.

Bradbourne Land.—In October 1939, after re-letting 100 acres of Park Farm to the sitting tenant, we took over some 78 acres in addition to the gardens and grounds, which occupy some 22 acres. Owing to the outbreak of war, of the 57 acres of this land, which had been in rough pasture for the last fifty-six years, nearly 50 acres have been put under the plough for purposes of food production, and at the time of going to press, there is a very promising stand of Victor wheat and Victory oats on this area. The remaining 7 acres have been laid in for hay.

Of the other 21 acres, 11 were in a one-year ley when taken over. The other 10 have afforded an admirable isolation ground upon which the East Malling clonal Yellow-edge-free stock of Royal Sovereign strawberry is being maintained with the consent of the County War Agricultural Committee at the special request of the Ministry of Agriculture.

The old orchard has been grubbed and cleaned and, with the spacious wall gardens, is in full use for the raising in isolation of disease-free selections of strawberry, raspberry and Golding hops.

Acknowledgement.—The writers of this report thank Messrs. J. Amos and F. H. Beard for the information upon which it is based.

Routine Spraying Programme. As in 1938, bad weather militated against tar-oil spraying before Christmas, for there were severe frosts and some heavy snowfalls. Afterwards it was little better because of persistent high wind and rain. The spraying had to be done at every favourable period. Petroleum spraying was similarly delayed, and, as a result of this, spray damage of two kinds was noted later. On the early Beauty of Bath apple there was direct scorching of the young rosette leaves, which were emerging from the fruit buds when the spray was applied. On certain varieties, however, particularly Cox's Orange Pippin and Bramley's Seedling, severe damage occurred on fruit buds, following the green-bud application of lime-sulphur with lead arsenate. Flowers and surrounding leaves were killed and hung dry and brown on the trees. The wood buds were delayed and dwarfed. A detailed survey of this damage in relation to the kinds and strengths of sprays used showed clearly that it was due to the application of lime-sulphur at 2% or more, with or without lead arsenate, following a late application of petroleum oil. No damage occurred where colloidal sulphur, or lime-sulphur at 1%, followed petroleum oil. The damage was possibly caused by interaction on the tree between lime-sulphur and the soap emulsifier of the petroleum oil, and was brought about by the necessarily short interval of only two weeks or so between the two spray applications. From this point of view it is therefore wise policy to complete essential petroleum oil spraying on apples before the end of March.

Severe damage to Victoria plums on one plot was caused by spraying on a very windy day in early March with winter petroleum oil emulsion. Other plums there were affected, but only slightly so. Because of the wind, the volume of spray used on this plot was 30% in excess of the normal. The damage was probably due to overspraying coupled with cold weather afterwards, when the buds moved but slowly. At blossom time the trees were still almost without sign of life, and the bark was blackish and oily; all the flower buds dropped out but the trees recovered later. Victoria is evidently specially susceptible.

Hot, sunny weather occurred during the second week of April after weeks of cold weather. All buds moved very rapidly and pre-blossom spraying for Scab, particularly that at pink-bud, was a little earlier than usual. Scab-infection, however, occurred later than usual, mainly in blossom time, and the spots were not visible until after blossom. Lime-sulphur was used at only 1½% on pears at white-bud because the warm weather had accelerated bud development and shortened the interval between green- and white-bud.

Very good control of Apple Scab and of Pear Scab was obtained. On apples, colloidal sulphur and soap was used instead of lime-sulphur, for the second post-blossom application, to obviate the risk of fruit-drop. The soap was used to ensure thorough wetting of any existing Scab infections. This spray was applied later than two weeks after petal fall, and would have been omitted altogether but for the appearance of a few late Scab infections here and there.

The only pest that became prevalent was Red Spider on apples, and this in spite of winter

petroleum. This pest multiplied rapidly in late summer, probably because lime-sulphur was omitted from the summer spraying programme. This raises a question of whether it is economic to spray with winter petroleum for Red Spider where Capsid is absent; experience on this farm suggests that some reliance on summer applications of lime-sulphur is still desirable.

Cottonseed oil again proved an efficient "safener" for Bordeaux mixture, but it makes the spray a costly one.

The three-nozzle head first introduced into the routine spraying in spring, 1938, was used very satisfactorily on all established fruit throughout the season. Trigger valves instead of screw-down taps seem to have come to stay, and they have well repaid their cost by reducing spray wastage.

The symbols used for the sprays are:

L.S. Lime-sulphur.
B.M. Bordeaux mixture.
A. Lead arsenate powder.
N. Nicotine.
C.S. Colloidal sulphur.
C.C. Colloidal copper.

ROUTINE SPRAYING PROGRAMME, 1939.

Period.	Spray used.	Hosts.	Sprayed against.
Jan. 5th to Feb. 14th ..	**Tar-oil emulsion** containing: 3 gals. strained anthracene oil, ½ gal. oleine, 1 lb. caustic soda	Apples, Pears, Plums, Cherries, Black and Red Currants, Loganberries and Gooseberries	**Aphis.**
Jan. 19th ..	**Tar-oil emulsion** containing: 6 gals. strained anthracene oil, 1 gal. oleine, 1½ lb. caustic soda	Morello Cherries. Double strength used for greater effect on Brown Rot pustules ..	**Aphis** and **Brown Rot** (*Sclerotinia laxa*).
Feb. 24th to Apr. 5th ..	**Petroleum-oil emulsion** containing: 6 gals. petroleum oil, 1 quart oleine, 6 oz. caustic soda	Black Currants and Gooseberries, Plums, Apples ..	**Capsid** (*Plesiocoris rugicollis* and *Lygus pabulinus*) and **Red Spider** (*Oligonychus ulmi*).
March 3rd-10th	**Petroleum-oil emulsion** as above but with 5 gals. oil	Plums only	**Red Spider.**
April 5th and 11th ..	**L.S.** (2 gals.)	Black Currants (*just pre-blossom*)	**Big-Bud Mite** (*Eriophyes ribis*).
6th and 8th	**L.S.** (2½ gals.) + **A.** (2 lb.) ..	Pears (*green-bud*)	**Pear Scab** (*Venturia pirina*) and **Caterpillar.**
12th	**B.M.** (6 lb. bluestone, 9 lb. hyd. lime)	Cherries (*just pre-blossom*) ..	**Bacterial Canker** and **Leaf Spot** (*Pseudomonas mors-prunorum*).
13th	**L.S.** (2½ gals.) + **A.** (2 lb.) ..	Apples (*green-bud*) and Pears (*white-bud*) interplanted. Lane's omitted because buds not far enough advanced ..	**Apple Scab** (*Venturia inaequalis*), **Pear Scab** and **Caterpillar.**
	L.S. (1½ gals.) + **A.** (2 lb.) ..	Apples (*green-bud*). Plot C2, a manurial plot, specially subject to spray damage ..	**Apple Scab** and **Caterpillar.**
14th-15th	**L.S.** (1½ gals.)	Pears (*white-bud*). Used lower strength because of short interval between green-bud and white-bud	**Pear Scab.**
17th-21st ..	**L.S.** (2½ gals.) + **A.** (2 lb.) ..	Apples (*green-bud*). Lane's omitted as above	**Apple Scab** and **Caterpillar.**
25th	**L.S.** (1 gal.)	Apples (*pink-bud*). Plot C2 ..	**Apple Scab.**
25th-29th ..	**L.S.** (2 gals.)	Apples (*pink-bud*). Lane's included this time	**Apple Scab.**
May 4th.. ..	**B.M.** (4 lb. bluestone, 6 lb. hyd. lime) + **cotton-seed oil** (3 quarts)	Pears (*petal-fall*). Conference omitted	**Pear Scab.**
10th and 15th ..	**Flowers of Sulphur**	Established Strawberries ..	**Powdery Mildew** (*Sphaerotheca Humuli*).
15th	**B.M.** (2 lb. bluestone, 3 lb. hyd. lime)	Loganberries (*pre-blossom*) ..	**Cane Spot** (*Elsinoë veneta*).
19th-30th ..	**L.S.** (1 gal.) + **N.** (8 oz.) ..	Apples (*petal-fall*). Except Bath, Rival, Newton, Lane's, Duchess Favourite, Edward VII, Charles Ross, Belle de Boskoop	**Apple Scab** and **Apple Sawfly** (*Hoplocampa testudinea*). Useful also against **Red Spider, Capsid** and **Apple Mildew** (*Podosphaera leucotricha*).
20th-30th	**C.S.** (5 lb.) + 0·25% **Soap** (6 oz. caustic soda, 1 quart oleine) + **N.** (8 oz.)	Certain Apples (*petal-fall*) requiring fungicide, but themselves sulphur-shy, e.g. Newton, or planted amongst sulphur-shy varieties	**Apple Scab** and **Apple Sawfly.** Useful also against **Capsid** and **Mildew.**

ROUTINE SPRAYING PROGRAMME, 1939 (*continued*).

Period.	Spray used.	Hosts.	Sprayed against.
20th-27th	**N.** (8 oz.)+0·25% **Soap**	Certain Apples (*petal-fall*) not requiring fungicide, viz. Lane's, Bath, Rival and Duchess Favourite	**Apple Sawfly.** Useful also against **Capsid.**
June			
14th	**N.** (8 oz.)+0·25% **Soap**	Strawberries	**Aphis** (*Capitophorus fragariae*).
16th and 17th	**B.M.** (4 lb. bluestone, 6 lb. hyd. lime)+**cotton-seed oil** (3 quarts)	Pears (*second post-blossom*). Conference omitted	**Pear Scab.**
17th	**C.S.** (5 lb.)	Pears (*second post-blossom*). Red Currants beneath	**Pear Scab.**
19th-23rd	**C.S.** (5 lb.)+0·25% **Soap**	Apples (*second post-blossom*). Lane's Duchess Favourite, Lord Derby, Chas. Ross and Edward VII omitted	**Apple Scab** and **Mildew.**
23rd-26th	**C.S.** (5 lb.)+0·25% **Soap**+**N.** (8 oz.)	Certain young Apples (*second post-blossom*). Duchess Favourite omitted	**Apple Scab, Mildew** and **Aphis.**
26th	**N.** (6 oz.)+0·25% **Soap**	Loganberries and Blackberries	**Aphis** (*Macrosiphum rubiellum*).
27th	**Derris** (2 lb.)+0·25% **Soap**	Raspberries	**Raspberry Beetle** (*Byturus tomentosus*).
27th	**N.** (6 oz.)+0·25% **Soap**	Young Apples	**Aphis.**
28th	**C.C.** (3·3 lb.)+**N.** (6 oz.)+**Derris** (2 lb.)+0·25% **Soap**	Loganberries	**Cane Spot, Aphis** and **Raspberry Beetle.**
29th	**Washing Soda** (20 lb.)+0·25% **Soap**	Gooseberries	**American Gooseberry Mildew** (*Sphaerotheca mors-uvae*).
29th and 30th	**N.** (6 oz.)+0·25% **Soap**	Hops	**Aphis** (*Phorodon humuli*).
July			
4th	**A.** (2 lb.)	Pears	**Codling Moth** (*Cydia pomonella*).
5th	**A.** (2 lb.)+**N.** (6 oz.)	Young Apples. Plot C2, Beauty of Bath omitted	**Codling Moth** and **Aphis.**
6th	**C.C.** (3·3 lb.)+**Derris** (2 lb.)+0·25% **Soap**	Loganberries. The inclusion of colloidal copper was an error. This was intended to be solely a second spray for Beetle	**Cane Spot** and **Raspberry Beetle.**
7th-14th	**A.** (2 lb.)	Apples. Early Victoria, Beauty of Bath and Grenadier omitted	**Codling Moth** (*Cydia pomonella*).
10th and 11th	**N.** (6 oz.)+0·25% **Soap**	Hops	**Aphis.**
13th and 14th	**B.M.** (5 lb. bluestone, 7½ lb. hyd. lime)+**cotton-seed oil** (3 quarts)+**N.** (6 oz.)	Hops (*pre-burr*)	**Downy Mildew** (*Pseudoperonospora Humuli*) and **Aphis.**
24th	**Flowers of Sulphur**	Established Strawberries	**Powdery Mildew.**
July 31st and Aug. 1st	**B.M.** (5 lb. bluestone, 7½ lb. hyd. lime)+**cotton-seed oil** (3 quarts)+**N.** (6 oz.)	Hops (*in burr*)	**Downy Mildew** and **Aphis.**
Aug.			
2nd	**Flowers of Sulphur**	Hops	**Powdery Mildew** (*Sphaerotheca Humuli*).
11th	**N.** (6 oz.)+0·25% **Soap**	Established Strawberries	**Aphis.**
14th and 15th	**B.M.** (10 lb. bluestone, 15 lb. hyd. lime)+**N.** (6 oz.).	Hops (*post-burr*)	**Downy Mildew** and **Aphis.**
16th	**Flowers of Sulphur**	Hops	**Powdery Mildew.**
28th	**B.M.** (4 lb. bluestone, 6 lb. hyd. lime)	Loganberries (*post-cropping*)	**Cane Spot.**
Oct. 23rd	**B.M.** (10 lb. bluestone, 15 lb. hyd. lime)	Sweet Cherries	**Bacterial Canker** (*Pseudomonas mors-prunorum*).
Nov. 13th	**B.M.** (10 lb. bluestone, 15 lb. hyd. lime)	Sweet Cherries (Schreckens only)	**Bacterial Canker** (*Pseudomonas mors-prunorum*).

(M.H.M.)

Section II

GENERAL REVIEW OF RESEARCH WORK

WITH LISTS OF PAPERS PUBLISHED DURING THE YEAR

I. POMOLOGY

By R. G. HATTON

A.—Tree Fruits.—The original trials of rootstocks found in commerce, planted some twenty or more years ago, are still yielding valuable indications not only of the comparative longevity of trees on different rootstocks but also of differential nutritional requirements manifesting themselves in later life. Rootstocks have remained a dominating factor in tree performance but, of those we have, even the best has some disadvantages. Attention has therefore been focused upon the breeding and selection of new varieties, combining all the good qualities desired. While these new rootstocks are being tested intensively in the nursery, possible methods of rapidly predicting their potentialities have been explored. The correlation of the anatomy of stem and root with subsequent horticultural performance has opened up a most promising line as a means of initial grouping and selection. One report has already been published and a second is in preparation. Thus, far from being complete, the rootstock investigations have entered a new era, based on the practical experience and theoretical knowledge accumulated in the last twenty-five years.

Further evidence that intermediate stem-pieces have produced an influence upon the final scion, only subsidiary to the rootstock, has been published, but the practical possibilities of improving methods of " double-working " in order to overcome stock-scion incompatibilities, particularly in pears, are being explored.

Fifteen-year-old trees, doing poorly on Northern Spy stock, were inarched with vigorous No. XVI, five years ago. They continue to improve both in foliage colour and growth when compared with the controls.

The methods elaborated for the successful " frame-working " of apple trees have been extended to pears, plums and cherries. A large collection of " gage " plums has been assembled, and many of these have been frame-worked on to Czar and Purple Egg trees, with the object of exploring the commercial possibilities of high quality dessert plums. Similarly a number of less valuable pear varieties have been frame-worked to Laxton's Superb and Williams' Bon Chrétien. The advantage of this method, however, is not confined to the rapid change over from an undesirable to a desirable variety. The provision of " frames " resistant to certain diseases, such as bacterial canker, and compatible both with stock and scion, is also aimed at. The influence of these whole trunk and branch intermediates upon the growth and fruiting of the grafted scions is being carefully studied.

The intimate study of the growth and development of fruit tree roots under different environmental conditions, both by detailed excavation and through observation trenches, has now been fully reviewed. Parallel with this work continuous records of soil temperature and soil moisture at two depths were obtained. The behaviour of the roots was in the main dictated by these two factors and a beginning was made in developing investigations on the practical methods of their control. The effects of irrigation, of various grass mixtures and cover crops, and of suitable cultivation treatments, are being explored. The roots of some cover crops are under observation.

It is obvious that the control of all these environmental conditions must profoundly affect the amount of plant foods available to the tree. At the same time the manurial trials in the field, which have now been summarized, have reached a point where it appears that the physical condition of the soil is becoming an all important factor in fruit tree nutrition. These lines of work have thus converged into a common problem and are being investigated as a whole. Collaboration with the Biochemical Section in the diagnosis of the nutritional status of the tree has been arranged, whilst the plant pathologist proposes to follow up the incidence of disease and spray damage upon these experiments.

The problems of fruit tree pruning, like those of rootstock, have changed as the trees matured. The recent findings that severe spur shortening in the winter following a heavy crop may bring strongly biennial trees nearer to regular cropping are being followed up on other varieties. Special pruning methods suitable for newly " frame-worked " trees, designed to bring the trees into fruiting without becoming biennial, are also being elaborated. The comparative trials of summer and winter pruning of apple cordons and dwarf pyramids are beginning to show differences.

The work on the failure of pear blossoms to set fruit, and the drop of young fruitlets, has been carried a stage further. It has been found that those flowers which set more regularly than others are associated not only with their position on the truss but with their relative size. The flowers are also larger generally in an " on " year than in an " off " year. The nutritional aspect of the problem is being followed up.

The investigations designed to elucidate conditions which govern the occurrence and severity of spring frosts and to explore possible methods of preventing damage are continuing along three lines. The fundamental studies of the inter-relationship of climatic factors such as wind, temperature, humidity, and certain cultural and topographical factors, such as altitude, grass and cultivation have added considerably to the information already available. The preliminary work on the actual circumstances and stages of frost damage to the blossom, under various conditions, has been followed by further experiments on commercial varieties for a second season, and these have in general confirmed the results of the previous work regarding the conditions and stages of blossoming under which various temperatures prove " killing " upon different varieties of apple. The possible value of the use of such things as glycerine and growth-retarding substances, either for spraying or injecting has been explored, so far without much promise of success. The differences in varietal susceptibility to frost damage revealed both in these studies and in our experimental plantations have concentrated work on the collection and selection of resistant varieties, and have resulted in the initiation of direct breeding for such characters as late blossoming and frost resistance.

A considerable number of the new seedling apples, bred in an attempt to obtain a succession of red dessert apples with Worcester Pearmain—McIntosh Red characteristics have now fruited. Early, mid-season and late representatives of these families have been selected for rapid propagation for further trial. Amongst those seedling crosses designed to provide a choice of late dessert apples, a surprisingly high proportion of those which had Cox's Orange Pippin as one parent showed some promise of quality.

In collaboration with the staff of the Ditton Laboratory, who have regularly used the fruit crops from the Station for storage experiments and who readily advise with regard to the Station's cold and gas stores, a considerable fund of information has accumulated with regard to the effects of differential orchard conditions upon market quality from store.

B.—Small Fruits.—Clonal healthy races of red and black currants are being maintained and a nucleus of the most promising varieties is being further propagated. Similarly, virus-free clones of 19 of the most promising raspberry varieties, in addition to Lloyd George, are being isolated and multiplied. Out of over 4,000 new seedling varieties, some fifteen which appear to be an improvement on any commercial sorts, are now being treated in the same way, with a view to a cropping trial ultimately.

The comparative cropping trial of the blackberry and dewberry varieties is revealing important economic differences. The simplest methods of propagation are being worked out for important varieties. The trial of four different methods of training and distances of planting has yielded valuable information of the great influence of these, both on resistance to Cane Spot disease and on cropping.

The selection and propagation of " virus-free " Royal Sovereign strawberry plants has continued. In the large-scale runner bed less than one plant per 1,000 needed roguing out for " Yellow Edge " or " Severe Crinkle ". Other superior strains of this variety, apparently free even from " Mild Crinkle ", have been secured for observation and multiplication purposes. This work has now been extended to other varieties, nucleus healthy stocks of which are being multiplied in isolation under close observation. New methods of arranging isolated blocks in the runner field have been tried and proved worthy of further testing ; both yield and labour costs are being taken into account.

The use of overhead irrigation apparatus once again produced increased crops of Royal Sovereign.

A number of selfed seedlings of Royal Sovereign, King George, Sir J. Paxton and Madame Lefebvre are now being tested, and interspecific hybrids have been raised for botanical and genetical studies.

C.—Walnuts.—The variety collection came through the spring with no frost damage. Many of the selected varieties bore small crops of from 12 to 30 nuts, but the trees are still very young and the autumn was wet, and some of these were soft shelled.

With a better choice of scion wood from these young trees, the greenhouse grafting proved very successful in 1939. Outdoor budding is still being investigated.

Publications during the Year

In Relation to Tree Fruits.

The Influence of the Intermediate in Double Worked Apple Trees : Nursery Trials of the " Stem-Builder " Process at East Malling. N. H. Grubb. J. Pomol., 1939, **17**, 1-19. (E148.)

A report is given of a trial of certain apple varieties used in Continental nurseries as " stem-builders " ; it is claimed on the Continent that standard trees on seedling stocks, double-worked on

stems of these varieties, give three advantages: stouter stems, a larger proportion of saleable trees, and larger heads. These claims are found to be at least partially justified. The claim that a larger proportion of good trees is obtained implies a reduction of rootstock influence on vigour; this is examined in detail by means of trees on seedling rootstocks and also by a comparison of trees on a dwarfing and a vigorous vegetative stock. Of the two second scion varieties used for the purpose, one, Early Victoria, appears to show the reduction of rootstock influence by the "stem-builder" intermediates plainly; the other, Newton Wonder, gives an indefinite result. The "stem-builder" intermediates may have influenced both the development of the biennial habit amongst the trees of Early Victoria on the dwarfing rootstock, IX, and the set of fruit of both varieties on IX, and of Early Victoria also on XII.

The Influence of "Stem-builder" Intermediates on Apple Root Systems. W. S. ROGERS, A. B. BEAKBANE and C. P. FIELD. J. Pomol., 1939, **17**, 20-26. (E146.)

The conformation and relative size of the root systems of twenty-four double-worked apple trees, excavated in detail, are illustrated and discussed. The trees were Early Victoria on rootstocks Nos. IX and XII with 5 ft. intermediate stem-pieces of Normanischer Ciderapfel and Early Victoria. The introduction of the "stem-builder" intermediate, Normanischer Ciderapfel, was found to have reduced the difference in size due to rootstock by invigorating the trees on No. IX. The morphological characteristics of the rootstocks were not influenced by the "stem-builder" intermediate. Observations on the main roots of 480 double-worked apple trees are presented. The series comprised Early Victoria and Newton Wonder each re-worked on 5 ft. intermediate stems of the same variety and on Noir de Vitry, Normanischer Ciderapfel and Gelber Trier'scher Weinapfel, on rootstocks No. IX, No. XII and a collection of seedlings. None of the intermediates materially altered the morphological characteristics of the rootstocks Nos. IX and XII, nor did they eliminate variations among the seedling rootstocks. "Root weights" consisting of the central part of the root system with the stock stem attached, were obtained for the 480 trees described above. The results are tabulated and stem : root ratios presented. The "root weights" showed that the difference in vigour of the root systems normally found between the dwarfing No. IX and the vigorous No. XII was not eliminated, though it was somewhat modified, by the introduction of the long "stem-builder" intermediates. Trees of Newton Wonder were found to have a higher stem : root ratio than those of Early Victoria. Little difference in stem : root ratio was found between trees worked with different intermediates.

The Influence of Intermediate Stem-Pieces in Double-worked Apple and Pear Trees. N. H. GRUBB. Sci. Hort., 1939, **7**, 17-23. (E149.)

Manurial Experiments with Apples and Pears at East Malling, 1919-1938. W. A. BANE. Sci. Hort., 1939, **7**, 24-32, and Rep. E. Malling Res. Sta. for 1938 (1939), 205-8. (E150.)

Rootstock Work at East Malling. R. G. HATTON. Sci. Hort., 1939, **7**, 7-16. (E151.)

Root Studies. VII. A Survey of the Literature on Root Growth with special reference to Hardy Fruit Plants. W. S. ROGERS. J. Pomol., 1939, **17**, 67-84. (E152.)

Pear Rootstocks from Seed. I. Experiments on Methods of Germinating Pear Seeds. H. M. TYDEMAN. Rep. E. Malling Res. Sta. for 1938 (1939), 103-9. (E153.)

Pear Rootstocks from Seed. II. Studies on the Variation in Seedling Pear Trees. H. M. TYDEMAN. Rep. E. Malling Res. Sta. for 1938 (1939), 110-14. (E154.)

Low Temperature Injury to Fruit Blossom. I. On the Damage caused to Fruit Blossom by Varying Degrees of Cold. C. P. FIELD. Rep. E. Malling Res. Sta. for 1938 (1939), 127-38. (E155.)

A Further Experiment on Thinning the Fruit of Victoria Plums. A. C. PAINTER and B. L. WATES. Rep. E. Malling Res. Sta. for 1938 (1939), 139-44. (E156.)

Pollination in the Orchard. H. M. TYDEMAN. Cherry and Soft Fruit Show Catalogue, 1939, 15-20. (E158.)

Root Studies. VIII. Apple Root Growth in Relation to Rootstock, Soil, Seasonal and Climatic Factors. W. S. ROGERS. J. Pomol., 1939, **17**, 99-130. (E160.)

Studies on the root growth of four fourteen-year-old Lane's Prince Albert trees on rootstocks E.M.I. IX and XVI, for four consecutive years, on deep sandy loam at East Malling, Kent, are described. The studies were made by means of special observation trenches provided with glass windows supported against the soil profile and normally protected from light. It was found possible to observe the position, time and rate of root growth, suberization and formation of laterals. The ultimate death and decay of some of the roots and secondary thickening of others was recorded. Root hairs and other features were observed with a binocular microscope; and photographs, illustrating the root life history, were obtained. Soil temperature was recorded at two depths. Soil moisture was measured at two depths by means of moisture tension meters devised for the purpose.

The growing apple roots were white and succulent, about 0·3 to 2 mm. diameter, bearing root hairs only 0·025 to 0·075 mm. long. The growth rate varied from nil to about 9·4 mm. per day; 3 mm. per day was common during active growth periods. Suberization of the root usually occurred

at the age of from a week to a month. The cortex then shrank and rotted away, leaving the central cylinder loose in its hole. Insects sometimes fed on the decaying roots, thus enlarging the passages, and aerating and cultivating the soil. The smaller roots usually died and disappeared. The larger ones usually persisted. Some developed relatively rapid secondary thickening, while others persisted without much swelling ; both types produced lateral roots. Root growth was closely correlated with soil temperature. Some growth, but very little, was found in winter, at soil temperatures from 35° to 45° F. Active growth began at temperatures from about 45° F. upwards and increased with rising temperature up to the maximum recorded, about 69° F. (at 8 in. deep). Similarly root growth decreased with falling temperature.

A check in root growth under warm soil conditions usually coincided with drying of the soil, and a fresh spurt of root growth usually followed its remoistening, provided it was still warm. The degree of dryness at which a check to growth occurred usually corresponded to a soil moisture tension of 30 to 40 cm. Hg, but sometimes even lower tensions appeared to cause a check. Thus, soil moisture appears to act as a limiting factor to root growth well before the wilting range is reached.

Soil moisture was usually plentiful from January to May, but from June or July, until the onset of the autumn rains, the rainfall was often not enough to replace the water removed by the trees, and the soil steadily dried out. Root growth began before the leaves unfolded, and continued after shoot growth ceased. Relatively rapid root growth usually began in March or April, increased to a peak in June or July, and then fell off. A second peak sometimes occurred a month or so later, and a further small peak usually followed the onset of the autumn rains. The response of root growth to soil temperature and moisture can be seen locally as well as generally. Thus, the bulk of root growth is lower down or higher up according to seasonal soil conditions. In the spring, as the upper layers of soil warm up first, most growth occurs there ; in the winter, most root growth is in the lower layers.

This work suggests that quick-acting fertilizers will be most effective if applied in early spring or early autumn, but that slower-acting manures can be utilized all the year round. Deep cultivation is likely to do more good and less harm if confined to the winter months.

Many growing roots were seen below a depth of 40 in., but about twice as much root growth was noted between depths of 3 in. and 23 in. as between 23 in. and 43 in. Greatest root concentration was usually at a depth between 5 in. and 20 in. The growth of the roots of different rootstocks showed great contrasts in amount, following the above-ground vigour characteristics of the stocks. There was little difference in appearance between the individual absorbing roots. There were indications that the root growth of the most vigorous stock, No. XVI, differed from that of No. I and No. IX in the following ways : it reached its first peak more quickly, its general absorbing root distribution was rather deeper, and its suberization rate was very slightly slower. The mean growth rate per root was similar for all stocks, therefore the greater amount of root of No. XVI resulted from the possession of more rather than of longer, absorbing roots.

The methods of observation are described and criticized. The vertical position of the windows, and their division into ½ in. squares, by which root growth can accurately be charted appear to give better results over long periods than previously employed methods.

Observation trenches of the kind described appear to have further wide possibilities for many types of root study under field conditions.

Root Studies. IX. The Effect of Light on Growing Apple Roots : A Trial with Root Observation Boxes. W. S. Rogers. J. Pomol., 1939, **17,** 131-40. (E161.)

Anatomical Studies of Stems and Roots of Hardy Fruit Trees. II. The Internal Structure of the Roots of some vigorous and some dwarfing apple rootstocks, and the correlation of structure with vigour. A. B. Beakbane and E. C. Thompson. J. Pomol., 1939, **17,** 141-49. (E162.)

Transverse sections were made of the roots of eighty-six four-year-old apple trees on Nos. VII and IX and on eight new clonal rootstocks, worked with Lane's Prince Albert. The new rootstocks were obtained by crossing the two dwarfing rootstocks Nos. VIII and IX. A striking correlation was found between the relative area of bark to wood, as seen in transverse section, and the vigour of the scion. Transverse sections of the roots were examined by means of a projection apparatus. Direct negatives were made on bromide paper, showing the structure of the wood of eight new rootstocks and of Malling rootstocks Nos. VII, VIII and IX. The photo-micrographs so obtained were then cut up into the four elements of the wood and weighed in the following groups : (1) fibres, (2) parenchyma, (3) vessels and (4) rays.

The percentage areas of fibres, vessels, rays and to a less extent, of parenchyma estimated from these photographic prints, was found to bear a marked connection with the vigour of the scion, the clearest connection with vigour being in the proportion of wood ray tissue. The four vigorous rootstocks Nos. VII, 45, 125 and 128, were found to have an almost equal amount of living and dead tissue in the wood, whereas the six more dwarfing rootstocks Nos. IX, 90, 9, 108, 29 and 99 showed

from twice to three times as much living as dead tissue. Counts of fibres and vessels in the wood revealed a clear break between the four vigorous and the six dwarfing rootstocks, the former having a larger number of vessels and nearly twice as many xylem fibres as the latter. No definite connection was found between the size of the wood elements and the vigour of the scion, but there was a tendency for the more vigorous rootstocks to possess larger vessels than the dwarfing rootstocks.

Landmarks in the Development of Scientific Fruit-Growing. R. G. HATTON. Agriculture in the Twentieth Century. Essays presented to Sir Daniel Hall. June 1939, 309-60. Oxford Univ. Press. (E164.)

Practical Methods of Frameworking Fruit Trees. R. J. GARNER and W. F. WALKER. Sci. Hort., 1939, **7**, 33-44. (Eg17.)

Studies in Nursery Technique : Shield-budding Treatment of Inserted Buds with Petroleum Jelly. R. J. GARNER and D. H. HAMMOND. Rep. E. Malling Res. Sta. for 1938 (1939), 115-17. (Eg18.)

Regrafting Fruit Trees by Framework Methods. R. J. GARNER. J. Minist. Agric., 1939, **46**, 176-87. (Eg19.)

Winter Pruning Trials with Apples at East Malling. N. H. GRUBB. Sci. Hort., 1939, 7, 24-32. (Ep10.)

An Apple Irrigation Trial Using Soil Moisture Meters. W. S. ROGERS. Rep. E. Malling Res. Sta. for 1938 (1939), 118-26. (P5.)

A Survey of the Investigation on the Propagation and Testing of Walnuts at the East Malling Research Station. A. W. WITT. Quarterly Journ. of Forestry, 1939, **33**, 3-16. (E140.) (Previously published in Rep. E. Malling Res. Sta. for 1937 (1938), 259-65.)

Horticultural Meteorology.

Frost and Fruitgrowing. C. E. CORNFORD. J. Minist. Agric., 1939, **45**, 981-91. (H35.)

Researches into the Cause and Prevention of Frost Damage. C. E. CORNFORD. Sci. Hort., 1939, **7**, 60-2, and Rep. E. Malling Res. Sta. for 1938 (1939), 209-12. (H36.)

Report of N.F.U. Conference on Spring Frost Damage to Fruit in 1938. Kent Fmrs' Jnl., 1939, **45**, 18-24. (H37.)

Weather Conditions during 1938. H. C. CHAPELOW and H. M. TYDEMAN. Rep. E. Malling Res. Sta. for 1938 (1939), 145-7. (H38.)

In Relation to Small Fruits.

" Leaf-Bud " Propagation of Loganberry, Youngberry and Blackberries. R. J. GARNER and D. H. HAMMOND. Gdnrs' Chron., 1939, **105**, 2715, and Rep. E. Malling Res. Sta. for 1938 (1939), 9-11. (Eg16.)

Results of Researches in Strawberry Growing. W. S. ROGERS, M. E. KING and A. M. MASSEE. Sci. Hort., 1939, **7**, 71-84, and Rep. E. Malling Res. Sta. for 1938 (1939), 223-4. (Esf39.)

Trials of Loganberries, Blackberries and Hybrid Berries at East Malling. A. B. BEAKBANE. Sci. Hort., 1939, **7**, 64-70. (Esf40.) (Revised and reprinted in the Annual Report of this Station for 1938, pp. 213-16.) (Esf41.)

II. STATISTICS AND RECORDS

By T. N. HOBLYN

A sound knowledge of biological variation is the basis of all field experiments. The Statistical Section was formed in 1927 with the object of studying the variation of horticultural material in all its aspects, to provide a foundation upon which to build up suitable methods of experimental design. This still stands as one of the main projects in the Section's programme. Although it has not often been found possible to carry out actual uniformity trials, except with some of the small fruits, the required knowledge has been gradually accumulated through the medium of the many and varied experiments designed and interpreted for other sections. Thus, year by year, it becomes possible to give better advice in the layout of new experiments and to adapt to greater advantage the well-known statistical tools in their interpretation. All this has needed, not only the routine examination of the numerical results of experiments, but the closest collaboration with the workers concerned and a detailed knowledge of the behaviour in the field of the complex and long-lived plants with which they are working.

This season it is possible to report a study initiated with the intention of throwing further light on the causes of variation. A study of the causes of variation in apple and pear trees on clonal rootstocks in the nursery has been in progress for the last two years, and records have been obtained

and analysed of the growth in the " maiden " year of trees of which the previous histories of the rootstocks and scions used had been observed in detail. While large variations in size and rooting of the rootstocks and source and position on the parent tree of bud-wood had little influence on the growth of apple trees in the first season, the largest quince rootstocks, provided they were well rooted, gave the best " maiden " pear trees. Further, differences in the source of bud-wood were shown to be a possible cause of variation in pear trees.

Small differences in manipulative methods in the processes of budding and grafting had little effect on the variation in the " maiden " trees, which always tended to even up to a marked extent during the season. But it was shown that the practice of " high snagging " might lead to a higher variability, unless all the buds were inserted on the rootstock with exactly the same aspect. These trees will be retained in the nursery for a further season to show how far differences so far observed will persist. A report on the results to date is in preparation.

The study of the variation between individual trees or bushes has in recent years been extended to include a more intimate examination of the variability to be found within a single tree. This applies both to differences between individual branches and to the size, quality or behaviour in store of different fruits.

On this knowledge are based methods of sampling which are now in use. Thus, during the past year, the harvesting and recording of a large crop under somewhat difficult circumstances has taxed the ingenuity of the workers in this and the Pomology Section. Methods of estimation have had to be devised to avoid the numerous weighings needed to record individual tree weights, and sampling methods developed in previous years have been used to estimate fruit size.

Apart from the plants which are the subject of experiment, studies are also being undertaken of the distribution of the insects which infest them. In collaboration with the Entomology Section two investigations mentioned last year have now been concluded. On the basis of the study made of the variation in the incidence of the strawberry aphis, *Capitophorus fragariae* Theob., a sampling technique for the comparison of infestations in commercial plantations has been recommended.

During the autumn months several new projects have been considered and experiments designed. Of particular interest are those dealing with the use of cover crops in established plantations. In these, as far as possible, future developments have been provided for. This has been done by using large plots, which can later be split up into small ones, on which can be superimposed further manurial or other treatments, or by allowing extra plots outside the main body of the experiment, which can be used to explore subsidiary issues.

Publication during the Year

Field Sampling for the Comparison of Infestations of Strawberry Crops by the Aphis *Capitophorus fragariae* Theob. R. M. Greenslade and S. C. Pearce. J. Pomol., 1940, **17**, 308-17. (D143.)
(For summary see under Entomology, p. 31.)

III. PLANT PHYSIOLOGY

By M. C. VYVYAN

Vegetative Propagation.—Work on the use of Plant Hormones for improvement in rooting of deciduous fruit plants has been continued, and some success has already been reported with soft-wood cuttings (F31), but little as yet with hard-wood. In 1939 the substances were tried on shoots in the layer beds. A new room with controlled temperature and humidity for the delicate " coleoptile " test for plant hormones has been built. A technical communication (F33) has been published which includes a general review of all recent developments in plant hormone research.

The rooting of plum cuttings from different sources, such as hedges, layers and bedded layers, was examined in 1939. Those from hedges gave the best results.

Etiolation, or blanching of bases of shoots, has long been known to favour rooting and is the basis of the practice of layering. The anatomical and physiological nature of the effect of etiolation is being examined to see if these throw any light on conditions necessary for rooting.

Growth of Stock and Scion.—Practically all the material used for growth or fruiting enters the plant either through the leaves or the roots. Carbon, which forms most of the dry weight, enters through the leaves. The amount of matter entering at any moment depends largely on the amount of these absorbing surfaces, though other factors play a part by influencing the rate of absorption. If the new material absorbed is used largely for formation of new absorbing surface, this increases rapidly and, in its turn, leads to more rapid absorption and growth. If the new matter is used for

less productive tissues, such as thickening of old stems, the rates of absorption and growth are slower. Roots and leaves are mutually dependent upon one another for materials required for growth.

Most of the work on these lines has been done on annuals and very little on grafted trees. In a worked tree these two organs, derived from rootstock and scion respectively, are of different varieties which may have different growth rates, or powers of absorption. In such a tree mutual adjustment may be expected in growth rates and distribution of growth, and these adjustments may be an important factor in the performance of any rootstock and scion combination. General investigations on the rates of growth and its distribution between root, stem and leaf, in worked and unworked apple trees, were started here some years ago to fill this gap in our knowledge. The work culminated in an experiment in which three varieties of apple stock were combined as rootstock and scion, in all nine possible ways. The last batch of these trees was lifted, cut up and weighed in the spring of 1939. Much useful information has been obtained. The results are in process of examination and will be published in due course.

Biennial Bearing.—The physiological reactions underlying Biennial Bearing are being investigated with the object of ascertaining the cause, leading eventually to devising methods for controlling it.

Spray Damage.—In collaboration with the Insecticides and Fungicides Section a study has been started of the physiological processes that lead to scorching and discoloration of foliage resulting from the application of fungicidal and insecticidal sprays.

Growth of Apple Trees in Water Culture.—The study of the nutrition of apple trees through water culture methods is being continued. The method has great experimental advantages. The exact chemical composition of the solution actually bathing the roots is under more rigid control than when soil, or even sand is used, and can be changed at any moment. The intake of each element can be followed, week by week, by analysing the residual solution to find out what has been left behind. The trees can be weighed at intervals to determine their growth.

The results of the 1938 experiment have been published (F34), and these Cox's Orange Pippin trees were grown on into 1939. They bore copious blossom and set a fair crop—about 3 lb. per tree on rootstock No. IX, and 1 lb. on No. XII. The fruits were very large but of poor quality, watery, with large cells.

A new experiment with a larger number of trees will be set up in the spring of 1940. Some of the trees will be grown in the open, others in the greenhouse, and two strengths of culture solution will be tried.

Publications during the Year

Note on the Effect of the Variety of Stock used to provide the Intermediate Stem-piece in some Double-worked Apple Trees. M. C. Vyvyan. Rep. E. Malling Res. Sta. for 1938 (1939), 148-56. (F30.)

Experiments with Growth Controlling Substances. II. The Response of Fruit Tree Cuttings to Treatment with Synthetic Root-forming Substances. H. L. Pearse. Rep. E. Malling Res. Sta. for 1938 (1939), 157-66. (F31.)

Plant Hormones and their practical importance in Horticulture. H. L. Pearse. Imp. Bur. Hort. and Plantation Crops Tech. Comm. No. 12, September 1939, 88 pp. (F33.)

Water-culture Studies with Apple Trees. II. The Seasonal Absorption of Nitrogen and Potassium by Cox's Orange Pippin on Malling Rootstocks Nos. IX and XII. H. L. Pearse. J. Pomol., 1940, **17**, 344-61. (F34.)

A method of growing apple trees in water-culture is described and the advantages of this procedure for growth and nutritional studies is indicated. Maiden trees of Cox's Orange Pippin budded on Malling rootstocks No. IX (dwarfing) and No. XII (vigorous) were successfully grown in continuously aerated aqueous solutions. The variability in development of the trees was less than that of similar trees in soil.

The usual effect of the rootstock type in controlling the degree of vigour of the tree was not affected by the method of culture. Trees on the vigorous rootstock, No. XII, bore blossom as freely as those on the dwarfing rootstock, No. IX. Trees on No. XII rootstock absorbed more water per unit leaf area throughout the growing season than those on No. IX. Trees on No. IX rootstock, absorbed more water per unit increase in fresh weight than trees on No. XII.

There was little qualitative difference in the course of nitrogen and potassium absorption for the two different types of tree. Trees on No. XII absorbed considerably more potassium per unit weight of tree in the early part of the growing season. While the trees on the vigorous rootstock absorbed considerably more potassium and nitrogen, the ratio of total growth made to the amount of each of these nutrients absorbed did not differ significantly for the trees on the two rootstocks.

The Response of Seeds and Seedlings to Treatment with Indolylacetic Acid. Y. Hwang and H. L. Pearse. Ann. Bot. Lond., 1940, **4**, 31-7. (F32.)

IV. BIOCHEMISTRY

By W. A. ROACH

A year's visit to South Africa provided a unique opportunity for testing methods of plant injection for the diagnosis of deficiencies on a large scale on a wide range of fruit plants. Contemporaneously the improved Ramage Flame method of Spectography was used for routine analyses of material collected both in South Africa and in this country. Some of the results of using these two complementary methods over such a wide range of material are given in a separate review.

The desirability of hastening the development of quick analytical methods for use side by side with plant injection necessitated the slowing down of the survey of the organic constituents of fruit trees and the entire concentration of effort upon these problems.

The general problems of nutrition arising in the experimental orchards are now affording material upon which each method can be developed. It is hoped to give the pomological section something in the nature of a "running commentary" on the nutritional status of the trees, which show obvious differential responses in the field trials.

Hence in the immediate future the main lines of work will consist of diagnostic and curative experiments in the field. These will include not only attempts to remedy by injection nutritional deficiencies but the control of insect and fungus pests.

Analytical methods will be developed to include more elements and the physiological function of certain of them will be explored. The factors affecting the uptake of minerals from the soil will also be studied by these methods.

The methods are being applied in commercial plantations in co-operation with the Advisory Officers and a varied range of practical methods are capable of use over a wide field.

Publications during the Year

Plant Injection as a Physiological Method. W. A. Roach. Ann. Bot. Lond., 1939, 3, 155-226. (K30.)

A review is given of the history of plant injection, going back to the twelfth century. Methods are described for injecting individual parts of a plant each with a different liquid, using the untreated parts for comparison. The methods may be used for several physiological purposes and especially for the diagnosis of mineral deficiencies. Such diagnosis may be carried out in as short a time as four days. Some of these methods have a high degree of statistical reliability.

Single interveinal areas of certain plants (e.g. apple, pear, strawberry, etc.) may be injected so that the permeated area is sharply separated by secondary veins from the untreated area on either side. This method is not applicable to the peach and the tomato. A leaf, after its apical quarter has been amputated, may be injected while still attached to the tree by immersing the cut edge. Similar treatment of the leaflet of a compound leaf in some plants (e.g. the strawberry) results in the permeation of one side of the adjacent leaflet, while the other side is not permeated. Injection, through a leaf-stalk left attached to the stem after the blade has been removed, results in the permeation of whole leaves and parts of leaves above and below the injection point, the "injection pattern" depending on the phyllotaxis and the vascular anatomy of the stem. In some leaves the midrib forms a sharp division between permeated and unpermeated blade tissues. Injection through a shoot-tip results in the permeation of a number of the terminal leaves. Branches may be injected independently of the rest of the tree through a suitably placed hole passing diametrically through the branch. The individual branches of certain trees may be injected each with a different liquid so that the corresponding roots are also permeated. Whole trees and other plants may be injected through a single diametrical hole, large ones through two or more radial holes. Uniform permeation of all the branches depends on the proper placing of the hole or holes in relation to the branches.

Examples are given of physiological and practical applications of these methods.

Plant Injection for the Diagnosis of Mineral Deficiencies. B. F. G. Levy. Sci. Hort., 1939, 7, 50-9, and Rep. E. Malling Res. Sta. for 1938 (1939), 235-43. (K32.)

Flame Method of Spectrochemical analysis. W. A. Roach. Nature, 1939, 144, 1047. (K33.)

Ramage's flame method of spectrochemical analysis has been rendered more sensitive and the results more reproducible. The roll containing the sample is introduced into ammonium chloride vapour to drive off volatile gases and convert the minerals into their chlorides before the roll is burnt in the oxy-coal-gas flame.

V. PLANT PATHOLOGY, MYCOLOGY AND BACTERIOLOGY

By H. WORMALD and R. V. HARRIS

A.—Diseases of Tree Fruits. The investigations on diseases of tree fruits have been directed chiefly towards Crown Gall, Brown Rot, and Bacterial Canker of plum and cherry trees.

Crown Gall.—Work on Crown Gall was undertaken when it was found that some of the apple rootstocks propagated on the Station were very susceptible to this disease. Detailed field observations and inoculation experiments showed that certain rootstocks were more susceptible than others. Recently it has been found, by inoculation experiments, that the size of the galls depends on the time of year when infection occurs. It has also been shown that galls may be produced by inoculations with certain "growth promoting substances" in the absence of bacteria.

Experiments have been designed to determine the effect of the organism on the subsequent growth of the tree.

Strains of the Crown Gall organism, *Bacterium tumefaciens*, have been isolated from a number of host plants (including raspberry, blackberry, and loganberry) and it has been found that the strains vary in their ability to infect certain hosts. Further work in this direction will aim at determining what strains most readily infect the apple and the cultivated species of Rubus.

In experiments on the control of the disease, promising results have been obtained with an organic mercurial preparation. In view of the possible difficulties of obtaining supplies of any particular product experiments will be carried out with other mercurial preparations.

Brown Rot.—The two species of Brown Rot that cause great damage to fruit trees in Britain attack also a number of ornamental shrubs. One of these fungi, *Sclerotinia fructigena* (*Monilia fructigena*) infects through the fruit only, but it may at times extend into the branches to form cankers. The other fungus, *Sclerotinia laxa* (*Monilia cinerea*) infects not only the fruit but also the young shoots, and particularly the flowers, to cause Blossom Wilt. As the primary means of control for the Brown Rot diseases is the removal of infected parts it is necessary to determine the various host plants of these fungi. Cross inoculations have shown that, in general, any one infected host plant is a potential source of infection for other hosts. It was found, for instance, that strains of *S. laxa* occurring on certain species of ornamental shrubs were able to infect the fruits of apple, pear, plum and cherry. Observations will be continued as occasion arises to ascertain what other varieties of trees or shrubs are hosts of the Brown Rot fungi.

For an account of spraying experiments against Brown Rot see under VII, Insecticides and Fungicides.

Bacterial Canker.—Round about 1925 many trees died on the plum trial plots on the Station from what was known at the time as Die Back, and the same disease was responsible for heavy losses in commercial orchards of plum and cherry. The disease was investigated and found to be caused by bacteria, chiefly by one which has been named *Pseudomonas mors-prunorum*; it infects the stems in the autumn, and when the stems are girdled by the lesions the trees die during the following summer. It was also found that the same organism causes leaf spot. It thus lives during the winter and spring in the stems, causing cankers, and during the summer and early autumn in the leaves. Control measures have therefore been directed towards protecting the trees from infection during each of these phases, by (*a*) spraying the stems in autumn, and the foliage in spring and summer, (*b*) producing resistant stems on which to graft the more susceptible but more valuable varieties, (*c*) avoiding pruning at times when the stems are liable to infection.

A special plot has been planted up in order that information may be obtained on these points. There are already indications that some varieties are more resistant to stem infection than others and such resistant varieties may serve as suitable frameworks for the susceptible varieties. Observations are being continued on this plot.

For an account of spraying experiments against Bacterial Canker and Leaf Spot see VII, Insecticides and Fungicides.

Further work will be directed to a search for a treatment which will be more effective than Bordeaux mixture at present recommended for spraying against Bacterial Canker. It is also proposed to attempt to raise disease-free trees of susceptible varieties.

Bacterial Blossom Blight of sweet cherries and Morellos (very severe on Morellos in 1939) is being studied with the object of determining its relation to bacterial canker and leaf spot, and of investigating means of controlling it.

B.—Diseases of Soft Fruits.—*Cane Spot of Raspberry, Loganberry and Phenomenal Berry* (*Elsinoë veneta*). A satisfactory control schedule for raspberry is now in practice. Further experiments will be made to improve this schedule by dilutions of the fungicide and by the use of modern substitutes for Bordeaux mixture.

An investigation of the disease on Loganberry and Phenomenal Berry was started in 1931. Early experiments and observations showed that the method adopted for raspberry was not completely effective on these crops, and that the seasonal cycle of the fungus differed in certain respects from that on raspberry. They also showed that the intensity of attack is related to the method of training the bine on the wirework. An experimental plot was planted in 1938 to determine the most effective combination of training and spray treatment for commercial plantations. In 1939 the complete spraying programme was applied to this plot, and the results indicated a marked reduction of diseases under certain spray treatments. A differential effect of training method was also shown.

Virus Diseases of Cultivated Rubi.—Raspberry Mosaic was transmitted to normal plants by grafting in 1926-27 and, owing to the failure to transmit mechanically or by insects, the analyses of symptoms since 1928 have been made solely by grafting. True grafting, however, proved laborious and unreliable and in 1937 the method of cane inarching was adopted. From the data obtained Raspberry Mosaic symptoms in this country are provisionally referred to two distinct categories : Mosaic 1 behaves as a single mild disease with comparatively restricted distribution ; Mosaic 2 includes diseases differing in intensity from mild to extremely severe and is widely distributed.

Some varieties rapidly succumb whilst others remain unimpaired for many years. Recent experiments have shown that Lloyd George and some other varieties react as symptomless carriers of Mosaic 2. The severe form of mosaic on Lloyd George is a combination of Mosaic 1 and Mosaic 2.

Experiments in commercial control from 1927 have been directed to maintaining supplies of mosaic-free cane from inspected and rogued nursery beds. This method, however, cannot be fully effective for those varieties with low symptom expression. The rapid testing of named and seedling varieties by direct infection and the use of indicator varieties was therefore started in 1939 and will be further developed.

In 1937 and 1939 the method of cane inarching was successfully used in the transmission and symptom analysis of the Dwarf Disease of Raspberry, Phenomenal Berry and other cultivated species of Rubus, and of a destructive Mosaic Disease of the Bedford Giant Blackberry. The latter disease has been shown to be distinct from Raspberry Mosaic.

Dwarf Lateral Scorch and Die-back of Raspberry and other Cultivated Rubi—A Functional Disorder. From 1930 onwards numerous enquiries have been received concerning a serious and widespread die-back and partial failure of certain varieties of raspberry (Lloyd George in particular), loganberry, and other cultivated Rubi.

The results of an experiment with Loganberry, Phenomenal Berry and Himalaya Berry started in 1937 and concluded in 1939, agreed closely with those of the 1937-38 experiment with raspberry, confirming conclusively that the disorder in all these crops is primarily caused by abnormally mild winter temperatures. Further experiments with special reference to direct control measures are being developed in collaboration with the Pomology and Physiology Sections.

Virus Diseases of Strawberry.—Two important diseases, Yellow-edge and Crinkle, are under investigation. Since the identification of the former on the variety Royal Sovereign in 1932, research has been directed to the development of a control system for that variety based on the maintenance of supplies of disease-free runners from systematically inspected and rogued propagation beds. The efficacy of this method depends on the degree to which infected plants exhibit symptoms. In field experiments from 1935 a seasonal fluctuation of symptoms shown by Royal Sovereign has been correlated with seasonal change in the plant environment and from these data the best times in a particular season for the inspection of runner nurseries of this variety can now be accurately predicted.

A comparison of the reactions of *Fragaria* spp. and of commercial varieties to Yellow-edge has shown wide differences in susceptibility and symptom expression, ranging from high resistance and complete absence of symptoms in the parent species *F. chiloensis* to the extreme susceptibility and continuous symptom expression of the other parent, *F. virginiana* and the common woodland strawberry *F. vesca*. From these results the final experimental determination of the reaction of each named and seedling variety to Yellow-edge becomes a paramount necessity. Having achieved this in some measure for Royal Sovereign, research is now being directed to other named and seedling varieties of both the susceptible and symptomless-carrier groups. The collection and testing of apparently virus-free plants of each selected variety was started in 1937.

In 1935-36 *F. vesca* was found to be a very sensitive indicator of Crinkle and to a lesser degree of Yellow-edge. By its use the clonal stock of Royal Sovereign raised at the Research Station and " rogued " for Yellow-edge was confirmed to be free from this disease but totally infected with Mild Crinkle.

In 1938 numerous samples of Royal Sovereign were procured from a local stock in Western Ireland (County Mayo) introduced in 1905 (shortly after the introduction of the variety to commerce) and subsequently cultivated in almost unbroken isolation from other varieties. Most of these samples, on grafting to *Fragaria vesca* proved to be entirely free from both Yellow-edge and Crinkle, and thus

provided material for etiological studies of the diseases and for the assessment of the commercial importance of Mild Crinkle. In 1939 therefore a small-scale pomological trial was laid down for comparing the performance of the Mild Crinkle infected clones of Royal Sovereign with clones raised from selected plants of the Irish strain.

Experiments to determine the relation of severe to mild crinkle were started in 1939 and the results indicate that plants are by no means homogeneous in their virus content, i.e. plants showing mild symptoms may be potential sources of the severe disease.

C.—Diseases of Hops.—See under VIII, Hops.

Publications during the Year

Notes on Plant Diseases in 1938. H. Wormald. Rep. E. Malling Res. Sta. for 1938 (1939), 167-72. (C150.)

Bacterial Rot of Cherry Fruits. H. Wormald. Rep. E. Malling Res. Sta. for 1938 (1939), 173-5. (C151.)

The Septoria Leaf Spot Disease of Black Currants. H. Wormald. Rep. E. Malling Res. Sta. for 1938 (1939), 176-9. (C149.)

Mosaic Disease of the Raspberry in Great Britain. II. Experiments in Transmission and Symptom Analysis. R. V. Harris. J. Pomol., 1940, **17**, 318-43. (C155.)

All experiments in the transmission of raspberry Mosaic by mechanical means have given negative results. Initial attempts in 1926-27 to transmit Mosaic symptoms to normal plants of the variety Baumforth's Seedling B by grafting yielded positive results, indicating the virus origin of the disease. Successful methods of transmission by cleft grafting, patch grafting and cane inarching are described.

Experimental work carried out from 1928 to 1937 on the analysis of the range of symptoms in some ten varieties of red raspberry by grafting is described. On the results of the experiments the symptoms are referred provisionally to two distinct etiological categories, Mosaic 1 and Mosaic 2. Mosaic 1 expresses type *b* symptoms on the indicator variety Baumforth's B, behaves as a single disease, probably of single virus origin, is uniformly mild in expression and of comparatively limited varietal distribution. Mosaic 2 includes diseases expressing type *c* symptoms on Baumforth's B, but differing in intensity of expression from mild to extremely severe.

Mosaic 2 is widely distributed among local varieties and these show a wide range of susceptibility to injury. Red Cross is totally infected but highly resistant, with an irregular expression of distinct leaf symptoms. No leaf symptoms have yet been expressed on artificially infected Lloyd George plants. Stools of susceptibles, e.g. Baumforth's B and Mitchell's Seedling, are rapidly rendered unproductive by severe Mosaic 2, and die. Combined infection with Mosaic 1 and Mosaic 2 has frequently been identified. The severe economic form of Mosaic in Lloyd George consists of such joint infection.

Diseases of Fruits and Hops. H. Wormald. Crosby Lockwood & Sons, Ltd., London, 1939, 290 pp., 40 plates and 24 figures in text. 17s. 6d.

For papers by W. G. Keyworth and D. L. G. Davies on diseases of hops, see under VIII, Hops.

VI. ENTOMOLOGY

By A. M. MASSEE and R. M. GREENSLADE

The main lines of work being studied by the Entomological Section are as follows : The Control of the Apple Blossom Weevil ; The Control of Woolly Aphis ; Strawberry Investigations ; The Insect and Allied Fauna of Raspberry ; Reversion of Black Currants and the Systematic Study of Gall Mites.

Apple Blossom Weevil.—Investigations on the control of Apple Blossom Weevil have been in progress many years, and partial control has been obtained by means of sack bands and corrugated cardboard bands used as traps.

This pest, however, is still causing considerable harm to young bush and cordon apple trees, and the possibility of using repellants to keep the weevils away from the tree at egg-laying time is being investigated.

Woolly Aphis.—The Woolly Aphis has proved a very difficult pest to kill by means of sprays and dusts because of its " woolly " protective covering, and spraying trials in the past have given very unsatisfactory results.

Further spraying trials are contemplated on a field scale—using mineral oil sprays and nicotine. Particular attention will be directed to the mode of application, since recent experience shows the importance of careful spraying.

The Insect and Allied Fauna of Rubus.—A knowledge of the insects and mites associated with cultivated Rubi has been accumulated gradually for several years, no less than one hundred and fifty species being recorded, amongst these a number of aphides and leaf hoppers.

Future work will be confined to the study of the possible insect vectors of raspberry mosaic and virus diseases of other species of Rubus. Such insects as the aphides and leaf hoppers, will be tested in the current investigations.

Strawberry Investigations.—During the past nine years a study has been made of the insects associated with strawberry, with special reference to the vectors of Yellow-edge and Crinkle virus diseases. It has been found that the Strawberry Aphis (*Capitophorus fragariae* Theob.) is a vector of both Yellow-edge and Crinkle, and it is able to transmit these viruses any time from the beginning of March to the end of November. Further, the apterous viviparous females, the winged forms, and the 1st and 2nd instar nymphs are all capable of transmitting the viruses.

Whilst the strawberry aphis is the only known vector of the strawberry virus disease of this country, it is imperative to discover if other insects of this soft fruit are associated with the rapid spread of these diseases in the field. Future work will be confined, therefore, to the study of other possible insect vectors.

In view of the importance of the aphis in commercial strawberry growing, detailed observations of the life-cycle are being made, and its movements during the migration periods are being closely watched.

Control measures have always presented great difficulties owing to the nature of growth of the plants, and spraying experiments have indicated that not more than 80 per cent. of the aphis population can be destroyed by spraying.

More recently the value of nicotine vapour for the control of strawberry aphis has been demonstrated, and further work to confirm the excellent results already obtained will be made in collaboration with Dr. W. E. Ripper. The experiments will be conducted in the field.

A method of comparing the relative abundance of the strawberry aphis in the field has been devised (in collaboration with the Statistical Section) and it is proving invaluable in aphis surveys which are being made in various parts of Kent. Further work is in progress.

A Study of the Vectors of " Reversion " of Black Currants.—It was found several years ago that the Black Currant Gall Mite is associated with the spread of " Reversion " of black currants. In recent years, however, " Reversion " has been prevalent in many plantations in the absence of the Black Currant Gall Mite. It is therefore proposed to carry out direct inoculation experiments with certain species of aphides and capsids in an attempt to find additional vectors.

Systematic Study of Gall Mites.—A systematic study of the Gall Mites (*Phytoptidae* (*Eriophyidae*)) has been undertaken for many years, and a large spirit collection has been obtained. This work will of necessity be curtailed at the present time, but it is hoped to add specimens to the collection from time to time.

Hop Investigations.—See under VIII, Hops.

Publications during the Year

A Species of Gall Mite (*Eriophyidae*) **injurious to Tomato.** A. M. Massee. Ann. and Mag. Nat. Hist., Series 11, 1939, **3**, 617-19. (D137.)

Notes on Some Interesting Insects Observed in 1938. A. M. Massee. Rep. E. Malling Res. Sta. for 1938 (1939), 180-5. (D138.)

The Control of Strawberry Aphis and Tarsonemid Mite. A. M. Massee and R. M. Greenslade. Rep. E. Malling Res. Sta. for 1938 (1939), 186-90. (D139.)

The Bramble Shoot-Webber, *Notocelia uddmanniana* L. G. H. L. Dicker. Rep. E. Malling Res. Sta. for 1938 (1939), 191-8. (D140.)

Suggestions for Control of Strawberry Aphis. R. M. Greenslade and A. M. Massee. Rep. E. Malling Res. Sta. for 1938 (1939), 250-2. (D141.)

Field Sampling for the Comparison of Infestations of Strawberry Crops by the Aphis *Capitophorus fragariae* Theob. R. M. Greenslade and S. C. Pearce. J. Pomol., 1940, **17**, 308-17. (D143.)

An account is given of a search for a method of sampling the population of *Capitophorus fragariae* Theob. in strawberry fields. The method devised consists of counting the aphides on a number of sample leaves, one leaf being taken from each of a number of equal sized blocks into which the field is divided. It is shown that the quantity $\sqrt{n+\frac{1}{2}}$, in place of the actual number of aphides on a leaf, n, enables considerably better comparison to be made between different samples. Evidence is advanced to show that the standard deviation of $\sqrt{n+\frac{1}{2}}$ within a block of less than 500 plants rarely exceeds 1·3.

Insects associated with Cultivated Forms of Rubus. G. H. L. Dicker. Trans. Soc. for Brit. Ent. 1939, **6**, 115-36. (D145.)

The Morphology and Biology of the Bramble Shoot-Webber, *Notocelia uddmanniana* L. (*Tortricidae*). G. H. L. Dicker. Ann. appl. Biol. 1939, **26**, 710-38. (D146.)

VII. INSECTICIDES AND FUNGICIDES

By H. B. S. MONTGOMERY, M. H. MOORE, H. SHAW and W. STEER

In recent years, methods have been developed for the laboratory testing of insecticides, fungicides, and bactericides, using as test organisms the Vapourer Moth (*Orgyia antiqua*), Winter Moth (*Operophtera brumata*), Green Apple Aphis (*Aphis pomi*), Red Spider (*Oligonychus ulmi*), Apple Sucker (*Psyllia mali*), Apple Scab (*Venturia inaequalis*), and the Plum Bacterial Canker organism (*Pseudomonas mors-prunorum*). These methods have been used to examine a wide range of materials, mainly synthetic organic chemicals, and some of these have shown sufficient promise to justify field trials. Among these are 3:5-dinitro-*o*-cresol, dodecyl thiocyanate, β-butoxy-β′-thiocyanodiethyl ether, and nicotine as ovicides, and tetramethylthiuram disulphide as a fungicide. Of the ovicides, 3:5-dinitro-*o*-cresol and β-butoxy-β′-thiocyanodiethyl ether seemed most worthy of extended trial, which is still in progress. Tetramethylthiuram disulphide just failed to give adequate control of Scab at a concentration economically practicable.

A particular study has been made of the ovicidal properties of tar and petroleum distillates. By using the several varieties of tar distillates available a selection of oils has been obtained ranging from wholly aromatic to non-aromatic material. The neutral portions of these oils have been isolated and fractionated according to boiling range. Of these fractions, the ovicidal properties and the chemical and physical properties have been determined and correlated where possible. The content of high-boiling neutral oil soluble in dimethyl sulphate is a satisfactory criterion of toxicity to Aphis only in the case of horizontal retort and of coke-oven tar distillates. Low-temperature tar oils and certain tar hydrogenation products show a wide divergence. In the case of Winter Moth it appears that boiling range is a principal, but not the only, factor determining ovicidal properties, and that viscosity is of major importance. The assistance of the Fuel Research Station, Greenwich, and of the Gas Light and Coke Company has been invaluable in this work.

Experiments with *Pseudomonas mors-prunorum* have provided interesting results on the significance of hydrogen ion concentration; the organism does not survive outside the approximate range pH 2·8 to pH 9·6. Mercury, silver, chromium, and copper, in that order, were the most toxic of eighteen metals tested as nitrates. Bordeaux mixture, however, was no more toxic than a suspension of calcium hydroxide of similar alkalinity.

In collaboration with the Department of Entomology, Imperial College of Science and Technology, the physiology of ovicidal action is being studied. It has been found that many ovicides do not inhibit embryo development even if applied at doses that prevent hatching. Using nicotine and the eggs of *Aphis pomi* it has been found that susceptibility is correlated with post-diapause development.

For several years the reactions occurring in sulphur-arsenate mixed washes have been under investigation. When mixed with lime-sulphur, calcium arsenate caused more damage to the trees than did lead arsenate. The addition of ferrous sulphate to either mixture reduced leaf-drop but not fruit-drop. In lime-sulphur-lead arsenate mixtures the amount of soluble arsenic liberated from a given amount of lead arsenate was found to decrease as the concentration of lime-sulphur was increased between 0·5% and 2·0%.

Spray damage is now being investigated in collaboration with the Physiology Section.

Investigations on the habits of the Codling Moth (*Cydia pomonella*) have shown that a second generation occurs only in some seasons and is comparatively unimportant, and that the main generation can be controlled by the use of lead arsenate late in June. In this connection trials on the influence of spray supplements on the deposition and retention of lead arsenate have shown that the effect of wetting and spreading agents, as well as of lime-sulphur, is negligible. The addition of 1% of a refined petroleum oil, however, increases the deposit.

Atomized Pyrethrum preparations have been tried out against the Raspberry Beetle (*Byturus tomentosus*) and the Apple Capsid Bug (*Plesiocoris rugicollis*). The beetles were readily affected by the atomized spray but almost invariably recovered. Apple Capsid nymphs were easily killed by contact with droplets of spray, but, as the nymphs are never all freely exposed, several applications are needed to achieve satisfactory results. Consequently the use of atomized Pyrethrum compares

unfavourably in cost with other available methods of Capsid control such as winter spraying with petroleum oil. A trial has been undertaken to ascertain the effect of the date of application of petroleum oil and of the lowest effective concentration.

A large scale field trial has been carried out for three seasons on Bramley's Seedling to ascertain the effect of omitting winter washes from trees that receive an otherwise normal spray programme that includes nicotine (for Sawfly) at petal fall. The attack of Rosy Aphis (*Anuraphis roseus*) has not exceeded negligible proportions throughout. No certain effect on Red Spider (*Oligonychus ulmi*) has been observed. Some evidence has been obtained that adult Red Spiders can be spread from tree to tree by the wind and so give rise to the late attacks of spider that are often observed even on trees that have been well sprayed with a Winter Petroleum.

In a search for a post-blossom spray for Big Bud (*Eriophyes ribes*) on Black Currants to take the place of the pre-blossom lime-sulphur which has been used hitherto, and which relies for its effect on the persistence of its deposit, it was found that concentrations of lime-sulphur as low as 1% caused severe injury. Derris and soap caused no injury as a post-blossom spray but appeared to be less effective than a pre-blossom application of 2% lime-sulphur.

With field work on fungicides, the main emphasis for many years has been on the best means of safely controlling certain diseases by spraying. Such diseases include Apple Scab, Pear Scab (*Venturia pirina*), Brown Rot (*Sclerotinia laxa*) in Morello Cherries, Bacterial Canker and Leaf Spot in Plums and Cherries, and Cane-Spot (*Elsinoë veneta*) in Loganberries.

The trend of research work on the control of Apple Scab is fully described in a separate article (see page 75). Suffice it to remark here that many spraying experiments have been made, involving the testing of many different times and methods of application and of different combinations of sprays and strengths, to find a safe and economic means of control. Special attention has been paid throughout to the possibility of combining insecticides and fungicides in one spray application to save time and expense. As a result much evidence has been amassed on the advantages and disadvantages of any one spray programme compared with others. Lime-sulphur has proved the most satisfactory all-round fungicide, but it is not perfect. A few promising sulphur-containing sprays have attained to field tests on a commercial scale, and considered judgment on their merits should be forthcoming in the near future. Meantime, some evidence has been obtained that the incidence of Apple Scab and of spray damage is influenced by manuring and by grassing-down. This promising line of work is being pursued.

A review of the present position and proposed future as regards the control of Loganberry Cane Spot will be found on page 68.

Brown Rot in Morello cherries can be effectively controlled by cutting out infections in early summer, and spraying in late winter with tar oil, with the additional safeguard in badly affected plantations of spraying just pre-blossom with Bordeaux mixture. Until further work on this problem seems warranted, the spraying trials will be discontinued.

Bacterial Canker in cherries can be controlled by spraying with Bordeaux mixture in autumn and spring, but there is as yet insufficient evidence that this is true also with plums. A new experiment has been designed and will shortly be started to obtain further evidence on this point. The leaf-spot phase in either host can be controlled by foliage applications of Bordeaux mixture with cottonseed oil added to render the spray safe.

Experiments on spraying apple trees in bloom will be continued in order to observe its influence on Scab control and the setting of fruit. The aim is to find a spray that, while bridging a danger period for Scab infection and permitting adequate fruit-set for a good crop, will yet sterilize some of the blossoms and thus counteract the tendency to biennial bearing. As seasonal conditions, apart from any spray treatment, have such an important bearing on pollination and fruit setting, it is evidently desirable to continue these studies over a number of years before any recommendation can safely be made. The work done so far has yielded promising results as regards Scab control, but there is as yet only meagre evidence as regards biennial bearing.

Branch-blister disease in apples is due primarily to drought and is associated also with lack of available potash. Collaborative experiments between the Insecticides and Fungicides and Pomology Sections are being continued on trees in pots to obtain further data on the effect of controlled watering and lack of potash on the incidence of the disease. Observations will be made on other functional disorders in relation to experiments on nutrition.

Up to the present Apple Canker (*Nectria galligena*) has been studied mainly as regards varietal susceptibility and the influence of rootstock. To explore the possibility of controlling the disease by spraying, however, an experiment, based on work recently done by Long Ashton, has been planned on some very susceptible trees to ascertain whether the results obtained at Long Ashton hold good under East Malling conditions. The incidence of canker will be studied also in relation to cover-crop treatments.

Recent Work on Fungicides and Insecticides at East Malling. M. H. Moore, W. Steer and H. Shaw. Sci. Hort., 1939, **7**, 85-94, and Rep. E. Malling Res. Sta. for 1938 (1939), 253-61. (Q15.)

Apple Scab Control. The Problem, and some recent Research Findings as regards its Solution. M. H. Moore. Fruitgrower, 1939, **87**, 569-70, and Rep. E. Malling Res. Sta. for 1938 (1939), 265-70. (Q17.)

Spray Residue Investigations. III. The Influence of Petroleum Oil and of Lime-Sulphur on the Retention of Lead Arsenate on Apples. H. Shaw and W. Steer. Rep. E. Malling Res. Sta. for 1938 (1939), 199-230. (Q18.)

Spray Residues on Fruit. H. Shaw. Chem. and Ind., 1939, **58**, 65, and Rep. E. Malling Res. Sta. for 1938 (1939), 262-4. (Q19.)

VIII. HOPS

A.—Varieties and Cultivation Trials.

By F. H. BEARD

Commercial Varieties.—A six-year trial with three clonal races of Fuggle has shown that strains botanically indistinguishable may show differences in cropping.

In the light of these results material has been collected from a number of selected gardens in order to raise disease-free and non-carrier strains from which a final selection can be made after field trials.

A disease-free collection of the chief Goldings has been raised and the varieties are now being propagated for use in cropping trials. Close observation has been kept on the varieties, but few consistent differences other than season, have been noted. It is likely that there are differences in cropping and possibly in quality which will come out in further trial.

New Varieties.—For over twenty-five years the Research Station has been the testing ground for the new varieties raised by Professor Salmon at Wye, and so far over 500 have been under trial. As a result of these trials it has been possible to select six varieties of sufficient merit to justify their introduction into commerce. In the preliminary testing records are taken on the yield and the incidence of disease. Samples are submitted for resin analysis and brewing tests. Professor Salmon publishes a report on this work annually in August, and an account of the incidence of Downy Mildew on seedlings of various parentages has been published.

The most promising seedlings are selected for planting on a larger scale and provide material for cultural and other trials.

Cultural Trials.—An account of these trials to date appears elsewhere in this report. (See page 76.)

Manurial Trials.—The original field manurial trials gave only very indefinite results largely owing to our lack of knowledge at that time on the control of the mosaic disease.

Pot culture experiments carried out a few years ago gave valuable data. It was established that certain foliage symptoms were associated with deficiency of certain elements. It was later confirmed that field trials with similar treatments showed the same symptoms.

At the present time the question as to whether a very vigorous variety of the New Mexican type will crop well when receiving only light nitrogenous manuring is being investigated.

Root Studies.—These investigations have only recently been started. A number of hills have been excavated by the skeleton method, and indicated that soil conditions greatly modify the root systems. It is hoped to publish an account of this work in the near future.

Observation trenches have been installed so that the rate of root growth can be noted and correlated with the soil moisture and temperature.

B.—Diseases of Hops.

By W. G. KEYWORTH and D. L. G. DAVIES

Verticillium Wilt of Hops.—During the present intensive study of this disease, started in July 1938, it has been found that outbreaks can be divided roughly into two classes : those in which disease intensity fluctuates annually, and those in which the disease becomes progressively more severe from year to year. Attention was mainly concentrated on the second class of outbreak since this appeared

likely to cause the greatest losses. Maps were made of affected gardens and it was seen that in Worcester-plant gardens cultivated in one direction only, the spread of disease was mainly in that direction, whereas in square-plant gardens cultivated in two directions at right angles to each other, the disease was spread irregularly over the garden. This suggested that the disease was being spread by the cultivation processes. The spread of disease by the planting of infected sets and by planting other crops infected with Verticillium Wilt, notably potatoes and raspberries, was indicated during the survey. Spores of *Verticillium albo-atrum* were discovered on the leaves of bines killed by the parasite.

Certain preliminary control measures were suggested on the basis of the 1938 observations.

During 1939 an attempt was made to determine by experiments the mode of spread of the disease and in addition to try to find a practicable method of soil disinfection. A trial of commercial varieties of hop for resistance to the disease was also laid down.

In 1939 experiments showed (1) that infected bine and leaves were potential agents in the spread of disease ; (2) that, in an experiment on small plots, 2% formalin applied to the soil at the rate of 8 gallons per square yard considerably reduced the amount of disease ; (3) that none of the commercial varieties tested was resistant to the disease.

On the basis of the 1938 and 1939 observations and experiments extensive experimental control measures are being applied on certain farms.

During 1940 observations will be made on disease incidence, especially on those farms already studied, in order to determine the effectiveness of the control measures now being applied. Further experiments are planned on soil disinfection and a test is being made on artificially infected ground of as many new seedling varieties of hop as possible in order to determine whether any show resistance to this disease.

Nettlehead and other Diseases of Hops.—Surveys of affected farms have been carried out in the South-Eastern counties and in the Midlands. These have shown that Nettlehead is more prevalent in certain hop-growing districts than in others ; there is more Nettlehead in the Weald than in East Kent, and more in Herefordshire than in Worcestershire. Maps have been made showing the distribution of Nettlehead on certain farms, and they indicate that in Worcester-plant gardens the diseased hills occur mainly in rows whereas in square-plant gardens they are scattered irregularly about the garden. The farm surveys are to be continued in 1940.

Two manurial trials have been laid down in order to determine whether the incidence of Nettlehead is influenced by the manurial content of the soil ; indications that this might be so were seen in an experiment on hop manuring in Herefordshire.

During the 1939 season, bines showing Nettlehead symptoms were marked on some farms. The cuttings from these bines have been collected and plants raised from them are to be used in grafting experiments which will be carried out both in the open and in insect-proof gauze houses. The objects of these experiments are to determine whether Nettlehead is transmissible by grafting and if so whether it bears any relation to Mosaic or other hop diseases.

Fuggle cuttings, obtained from fifteen apparently disease-free gardens, are to be planted under insect-proof conditions with the object of selecting the best of them from which to raise clones of disease-free Fuggle hops.

In addition to the work on Nettlehead, preliminary surveys have been made of the incidence of Mosaic, and of other hop diseases including Split Leaf, Split Leaf Blotch, Fluffy Tip, Armillaria disease, Fusarium canker and Small-hop disease.

C.—Entomological Investigations.

By A. M. MASSEE

The main Entomological problems under investigation are as follows : A study of the insects and allied fauna of the hop ; the insect transmission of hop mosaic ; the hop strig maggot and the hop red spider.

Hop Mosaic Insect Transmission. Work has been in progress during the past two seasons in an attempt to discover the insect vectors of hop mosaic. This problem entails a sound knowledge of the insects and mites associated with the plant, and a complete survey is being made.

Since the species of insects with sucking mouth-parts are the most common vectors of virus diseases, these insects are being studied in some detail. Direct inoculation experiments will be made with certain species of aphides and leaf hoppers under insectary conditions.

The Hop Strig Maggot. The Hop Strig Maggot is increasing very much in many parts of Kent, and it is now causing serious damage to the developing cones in many gardens. Therefore a study of the life-cycle is being made under field conditions, with particular reference to the emergence of the fly from the soil, and of the period of egg laying.

Hop Red Spider.—Phytocidal tests with lime-sulphur have been made in the latter part of May and in June to determine whether this spray can be applied early in the growing season, and thus avoid clashing with the routine application of Bordeaux mixture.

Very promising results have been obtained, and the experiment will be repeated again on several varieties of hop.

Publications during the Year

Twenty-second Report of the Trial of New Varieties of Hops, 1938. E. S. Salmon. August, 1939. (B33.)

Of the 223 varieties (New and Commercial) tested, seven New Varieties cropped at the rate of 25 cwt., or over, to the acre, and forty-three at over 20 cwt. The number of bushels (Imperial) of green hops required to the cwt. of dried hops varied from 84 to 152. Twenty-five New Varieties proved on analysis to be richer in preservative qualities than the richest old variety (Early Bird). Two of the New Varieties, viz. C9a ("Brewer's Gold") and Q43 ("Bullion Hop") were richer in preservative qualities than the richest sample of American hops obtainable—"Brewer's Gold", P.V. 14·45, by 1·02 per cent., and "Bullion Hop", P.V. 14·17, by 0·74 per cent.

A Table is given of the preservative values of growths of the above-named varieties produced abroad. It is pointed out that certain of the New Varieties have been shown by brewing tests to be equal, or superior, to the best imported American hops in preservative qualities and superior in flavour. An additional hop acreage in this country of some 3,000 acres would produce a crop capable of replacing the imported American hops, the average annual value of which for the four-year period 1934-7 under the Hops Marketing Board Scheme was £250,166.

The incidence of Mosaic Disease, Downy Mildew and *Verticillium* Wilt is reported.

A Report of Hop Research Work at East Malling Research Station. R. G. Hatton and F. H. Beard. Journ. Inst. Brewing, 1939, **45**, 556-9, and Kent Fmrs' J., 1939, **46**, 162-5. (B34.)

Verticillium Wilt of Hops. A Summary of Observations during 1938. W. G. Keyworth. Rep. E. Malling Res. Sta. for 1938 (1939), 244-49. (C152.)

Verticillium Wilt of Hops. A Summary of Observations during 1938 and 1939. W. G. Keyworth. Kent Fmrs' J., 1939, **46**, 217-21. (C154.)

Nettlehead and other Diseases of Hops. W. G. Keyworth and D. L. G. Davies. Kent Fmrs' J., 1940, **47**, 56-8. (C156.)

A Survey of Hop Diseases in Worcestershire and Herefordshire. D. L. G. Davies. Kent Fmrs' J., 1940, **47**, 62-3. (C157.)

IX. TECHNICAL SECTION

By N. B. BAGENAL

The Technical Section has continued to act as a link between the research programme at home and the commercial plantations of our members. A small preliminary trial in the training of dwarf pyramid trees has been established and a pruning trial of cordon pears has been supervised. Liaison has been maintained between growers and the research work on bacterial canker of plums and cherries, and on the injection of fruit trees. Contact with growers through the medium of the press was maintained by the publication, with the co-operation of the research staff, of twenty-two popular bulletins or leaflets in various topical journals, periodicals and newspapers.

Publications during the year

Fruitgrowing for Small Gardens. N. B. Bagenal. The Country Life Home Front Series for Intensive Cultivation, No. 5, 1939, 30 pp. (E163.)

A short account of the principles of fruit growing as applied to garden conditions. With the war many gardeners have had to make provision for the inclusion of fruit and vegetables in parts of the garden formerly devoted to flowers, shrubs and lawns. This book attempts to show how the special needs of fruit plants can be dealt with under these new conditions brought about by the war.

Black, Red and White Currants. N. B. Bagenal. Gardening Illustrated, 1939, **61**, 42-3. (Esf.38.)

A popular article on varieties suitable for garden culture with brief descriptions of each and some cultural notes.

Fruit Growing. Modern Cultural Methods. N. B. Bagenal (edited by). Ward, Lock & Co., Ltd., London, 1939. 8 plates in colour, 60 photographic illustrations and many diagrams. 21s. net.

Section III

RESEARCH REPORTS

POMOLOGY

THE PRESENT STATUS OF RESEARCH IN ROOTSTOCK PLANTS AND THE USE OF ROOTSTOCK PLANTS*

By R. G. HATTON

SINCE no varieties cultivated for fruit in England breed true from seed, vegetative reproduction is always used. Budding and grafting on to rootstocks is used because most varieties do not reproduce readily from cuttings or layers, and also because grafting was reputed to hasten fruiting.

Fruit Trees on Their Own Roots.

Many attempts have been made at East Malling to obtain varieties on their own roots by economic methods.

(i) *Apples.*

Four varieties (seventy trees) on their own roots and comparable trees on Doucin (No. II) and a vigorous (No. XV) rootstock were observed for eleven years. Although all " own-rooted " trees were smallest for five years, subsequently they made the biggest trees with three varieties, though their total crops exceeded those from trees on vigorous No. XV but were less than those on No. II. However, Manx Codlin remained more dwarfed on its own roots than when budded on either rootstock, and cropped more poorly than it did on No. II (Hatton, 1930 ; Hatton *et al.*, 1936).

Twenty-six other varieties have, with difficulty, been established on their own roots and have grown and cropped with varying success. Their rooting habits are very distinct.

(ii) *Pears.*

Pears have generally only become established on their own roots when the unions are planted below the soil level on incompatible quince rootstocks, and such trees become " scion-rooted ".

Then they have later made very erect, vigorous and infertile growth, have often developed Scab (*Venturia pirina*), and subsequently Canker (*Nectria galligena*) (Hatton and Bagenal, 1934).

(iii) *Plums and Damsons.*

Varieties such as Cambridge Greengage, Yellow Egg, Warwick Drooper, Prune Damson and other local varieties, have long been grown successfully on their own roots. Three hundred trees in three field trials, showed after ten and thirteen years, that, with one exception, those budded on Malling selection Myrobolan B (*Prunus cerasifera*) are still growing more vigorously than those on their own roots. Those on Common Plum are always more dwarfed. However, the " own-root " trees have so far cropped as well as, and in the case of Victoria, better than, those budded on to rootstocks (Hatton, 1936).

The behaviour of cultivated fruits upon their own roots appears then to differ with each variety. There is evidence that a variety can be dwarfed, and sometimes brought into fruiting more rapidly by the use of rootstocks ; and that at least up to thirteen years some apples and plums grow much more vigorously when budded upon certain rootstocks than they do on their own roots. The fruiting of seedling apples has been hastened by the use of Jaune de Metz (No. IX) (Tydeman, 1937*a*).

Since the difficulties of raising fruiting varieties commercially on their own roots are not yet overcome, and the size and cropping of trees can be controlled by the use of rootstocks, the practice is likely to persist.

Selection and Classification of Rootstocks.

(i) *Apples.*

Of the original varieties described, isolated and propagated at East Malling (Nos. I to XVI) (Hatton, 1917, 1919), and of those recently described by Floor and Zweede (1937) (Nos. XVII and

* Presented at the XIIth International Horticultural Congress, Berlin, August, 1938—National Report for Great Britain.

XVIII), Nos. IX (Metz), IV (Holstein), VII (unnamed), I (Broadleaf), and II (Doucin), XVI (Ketziner), and XII (unnamed), have shown outstanding qualities. Although their behaviour has varied somewhat with different scions, soils and climates, their potentialities up to eighteen years are generally predictable. Nos. V (Amelioré), VIII (French), and X (unnamed), have generally proved unsatisfactory, the rest mediocre.

The attempted grouping by East Malling according to vigour needs modification, since a really satisfactory rootstock for "semi-dwarf" bushes as required in Europe is still lacking. Again, the particular suitabilities of Nos. I and II to different scions, soils and climates need further study (Hatton, 1935).

East Malling has found and described six further layered apple stocks circulating amongst nurserymen.

Many additional rootstocks are now under trial, combining special qualities. Some Long Ashton layered selections of seedling "Free" stocks appear to combine influence for vigour and early cropping (Spinks, 1931). Definite crosses made by the John Innes Institution and East Malling between Northern Spy and Nos. IX, I, II and XII, have produced 800 hybrids immune to Woolly Aphis (*Eriosoma lanigerum*) for selection (Crane, 1937). Four of these "immunes" have already shown differences in vigour and cropping of seven-year-old trees and are under trial in several countries (Tydeman, 1935). Inter-crosses between non-immune rootstocks have produced hybrids apparently more dwarfing than No. IX, and, up to seven years old at least, as vigorous as, but more precocious than, No. XII at comparable age (Tydeman, 1937*b*).

(ii) *Pears.*

(a) *Quinces.* Only the selections described as Malling A, B and C have so far proved of commercial value for a limited number of varieties (Hatton, 1933).

Up to eighteen years Quince C has often proved most dwarfing and productive but in some cases is weaker at the union. Three hundred Russian "wilding" quinces are being tested with three varieties in the hope of finding more widely compatible quinces. These already show striking differences (Tydeman, 1937*c*).

(b) "*Free*" *pear* Malling selections (especially C2, 5, 6, 7, 8) have produced at fourteen years trees of different sizes and cropping capacity with two varieties (Hatton, 1933), but have hitherto been difficult to propagate commercially. Since large numbers are not required, the use of auxins may solve the difficulty (Pearse and Garner, 1937). Selection of seedlings from individual "mother" trees is also being tested.

It remains a problem in England to produce suitable bush trees of Bon Chrétien and other valuable varieties without double-grafting over quince. Appropriate intermediate scions have been tested (Grubb, 1927), but the method is so far slow and expensive.

(iii) *Plums.*

Eight important layered rootstocks have been tested from twelve to fifteen years with fourteen varieties. Differences in vigour, early cropping, ripening time and total crop, have been demonstrated at East Malling and Long Ashton (Hatton, 1936; Swarbrick, 1936). Scion, soil and climate affected the results but in nearly all cases trees on Myrobolan B are most vigorous, those on Common Plum, which definitely imparts resistance to Silver Leaf (*Stereum purpureum*), Brussels and Common Mussel, most dwarfed.

Trees on Yellow Egg, which is difficult to propagate, and Marianna have, for their size, cropped heavily; with one exception, trees on Brussels have behaved poorly. Unfortunately no single rootstock is compatible with all varieties.

Seedlings of St. Julien, Black and White Damas, Kroosjespruim, etc., have proved very variable.

A number of further selections have been tested to find better dwarfing rootstocks. After five years several are very promising. New crosses have also been made.

(iv) *Peaches.*

Trials with pot- and wall-trained Hale's Early peaches have shown Brompton, Damas C, Common Mussel and St. Julien A to be the most satisfactory rootstocks for peaches (Witt and Garner, 1931).

Clonal peach stocks are not yet available in quantity.

(v) *Cherries.*

Seventeen clonal selections of *Prunus Avium* (Mazzard), two of *P. Mahaleb*, and two of *P. Cerasus* have been tested with three acid varieties from fourteen to sixteen years.

Many selections of Mazzard propagate readily from layers, produce more even standards than seedlings, and differ in their influence on growth and cropping (Grubb and Witt, 1925). F12/1 and F5/4 are now recommended for vigour and semi-dwarfing.

Three sweet cherry varieties on fourteen Mazzard selections, twelve years old, show differences in growth and cropping.

Morello on Mahaleb selections has proved short lived, and on *P. Cerasus* trees are very dwarfed (Grubb, 1933). Promising clones of *P. Cerasus* are being raised for trials of sweet cherries as bush trees.

Rootstocks for ornamental cherries are also being tested.

(vi) *Walnuts.*

Vegetatively propagated races of *Juglans regia, nigra, Californica, sieboldiana,* and certain hybrids are being tested as rootstocks (Witt, 1936).

Of all species, 500,000 experimental rootstocks are raised annually at East Malling, and standardized rootstocks are in general commercial use.

Incompatibility of Rootstock and Scion.

Twenty years' experience in the experimental nurseries has revealed many data of practical importance in avoiding unsuitable scion-stock combinations (Amos *et al.*, 1936).

The literature of the subject has been reviewed both for the nurserymen and scientists (Argles, 1937).

Intensive investigations have elucidated the symptoms and immediate reasons for, and suggested some ultimate causes of, the phenomenon (Chang, 1938).

The Source of Rootstock Influence.

Investigations have been carried out to determine whether the actual root system or the stem-piece of the rootstock has more influence. It has been suggested that the influence lies entirely in the stem-piece (Roberts, 1929).

At East Malling it has already been shown that piece-roots of No. IX effectively dwarfed and brought into early cropping two varieties grafted directly thereon (Hatton, 1931). A further 108 apple trees, eight years old, grafted directly on to the roots of Nos. IX, II, and the very vigorous No. XII, and grafted upon 5 and 18 cm. of rootstock stem, demonstrate that whilst the trees grafted directly upon piece-roots show all the typical influence of the various rootstocks those with long stem-pieces give slightly greater contrasts (Beakbane *et al.*, 1937). Vyvyan (1938) also demonstrated on 112 trees, six years old, using Jaune de Metz (IX) and very vigorous No. XII both as the rootstocks and as the intermediate stem-pieces (15 cm. long), each on each, that whilst these stem-pieces have a measurable effect, it is small compared with the influence of either type of root-system.

Swarbrick, under conditions at Long Ashton, using 112 trees, obtained an even greater influence for the stem-piece (23 cm. long) and suggests that its use on seedling roots suffices to produce typical "stock effects".* Even if these conditions were general, double-worked trees are commercially expensive, but would at least be justified where problems of incompatibility, resistance of the stem to specific diseases or frost injury, need consideration. Knowledge of the influence of intermediate stem-pieces is also valuable because vigorous straight stemmed "stem-builder" intermediates have been used commercially in West England and on the Continent. However, in a recent experiment lasting five years, 152 cm. lengths of three such "stem-builders" completely failed to obliterate typical effects of Nos. IX and XII on two very different top scion varieties (Garner and Grubb, 1937).

The fundamental causes of rootstock effect are being analysed physiologically (Pearse and Vyvyan, 1937) and bio-chemically (Roach, 1935).†

Summary.

Experience shows that the use of rootstocks, with a few exceptions, is likely to continue owing both to the difficulty of propagation otherwise, and to their value for controlling size, crop and other characteristics.

The growth of apples and plums on their own roots is compared with that on various rootstocks. Scion rooting of pears on quince is discussed.

It is suggested that in certain cases rootstock propagation may be facilitated by the use of auxins.

* From unpublished papers consulted by kind permission of the Long Ashton Research Station.

† See also Reports on the work of Agricultural Research Institutes and on certain other agricultural investigations in the United Kingdom, 1934-35. *Long Ashton Research Station, University of Bristol,* page 52. H.M. Stationery Office, 1937.

Investigations into the source of rootstock influence are described. While the importance of an intermediate stem-piece is recognized, it is suggested that the root portion of the rootstock generally has more influence than the stem portion.

Advance has been made in practical and theoretical knowledge of incompatibility.

Incompatibility can be avoided and resistance of trunks to disease and frost injury achieved by the use of intermediates and stem-builders.

The present position with regard to apple, pear, plum, peach and cherry rootstocks after from twelve to eighteen years' trial is reviewed with special mention of particularly good and particularly poor stocks.

Attention is drawn to a number of new apple, plum, cherry and quince rootstocks which combine desirable characteristics and are now on trial.

Clonal rootstocks of walnuts, *Juglans regia*, are being raised and tested.

References

Amos, J., Hoblyn, T. N., Garner, R. J. and Witt, A. W. (1936). "Studies in incompatibility of stock and scion. I. Information accumulated during twenty years of testing fruit tree rootstocks with various scion varieties at East Malling." *Rep. E. Malling Res. Sta. for 1935*, **A19**, 81-99.

Argles, G. K. (1937). "A review of the literature on stock-scion incompatibility in fruit trees, with particular reference to pome and stone fruits." *Imp. Bur. Fruit Prod. Tech. Comm.* **9**, 115 pp.

B[eakbane], A. B., H[atton], R. G. and A[mos], J. (1937). "Mechanism of rootstock effect." *Rep. E. Malling Res. Sta. for 1936*, **A20**, 31, and unpublished work.

Chang, W. T. (1938). "Studies in incompatibility between stock and scion, with special reference to certain deciduous fruit trees." *Journ. Pom. and Hort. Sci.*, **15**, 267-325.

Crane, M. B. (1937). "Breeding immune rootstocks." *Ann. appl. Biol.*, **24**, 188-95.

Floor, J. and Zweede, A. K. (1937). "Handleiding voor de determinatie van Appelonderstammen." *Uitgegeven door den Nederlandschen Algemeenen Keuringsdienst.*

G[arner], R. J. and G[rubb], N. H. (1937). "Double Working." *Rep. E. Malling Res. Sta. for 1936*, **A20**, 37.

Grubb, N. H. (1927). "Experiments with double-worked pears on quince stocks." *Rep. E. Malling Res. Sta. for 1925*, **A7**, 11-15.

——— (1933). "Cherry stocks at East Malling. I. Stocks for the Morello Cherries." *Journ. Pom. and Hort. Sci.*, **11**, 276-304.

——— and Witt, A. W. (1925). "Cherry Stocks. Their behaviour in the nursery." *Rep. E. Malling Res. Sta. for 1924*, **A5**, 87-92.

Hatton, R. G. (1917). "Paradise Apple Stocks." *J.R. hort. Soc.*, **42**, 362.

——— (1919). "A summary of the results obtained in selecting and propagating Paradise stocks." *Gard. Chron.*, **65**, 71, 82, 100.

——— (1928). "The behaviour of certain pears on various quince rootstocks." *Journ. Pom. and Hort. Sci.*, **7**, 216-33.

——— (1930). "The relationship between scion and rootstock with special reference to the tree fruits." *J.R. hort. Soc.*, **55**, 169-211.

——— (1931). "The influence of vegetatively raised rootstocks upon the apple, with special reference to the parts played by the stem and root portions in affecting the scion." *Journ. Pom. and Hort. Sci.*, **9**, 265-77.

——— (1933). "'Free' or seedling rootstocks in use for pears. Their description, vegetative propagation and preliminary testing." *Journ. Pom. and Hort. Sci.*, **11**, 305-34.

——— (1935). "Apple rootstock studies. Effect of layered rootstocks upon the vigour and cropping of certain scions." *Journ. Pom. and Hort. Sci.*, **13**, 293-350.

——— (1936). "Plum rootstock studies. Their effect on the vigour and cropping of the scion variety." *Journ. Pom. and Hort. Sci.*, **14**, 97-136.

H[atton], R. G., A[mos], J. and B[eakbane], A. B. (1936). "Mechanism of Rootstock Effect." *Rep. E. Malling Res. Sta. for 1935*, **A19**, 28-9.

Hatton, R. G. and Bagenal, N. B. (1934). "Scion rooting at East Malling Research Station." *Rep. E. Malling Res. Sta. for 1933*, **A17**, 243-6.

Pearse, H. L. and Garner, R. J. (1937). "A note on the use of α-naphthalene acetic acid for rooting soft-wood cuttings of fruit tree stocks." *Journ. Pom. and Hort. Sci.*, **15**, 248-51.

P[earse], H. L. and V[yvyan], M. C. (1937). "Analysis of growth relations of stock and scion." *Rep. E. Malling Res. Sta. for 1936*, **A20**, 57.

R[oach], W. A. (1935). "Mutual influence of Rootstock and Scion." *Rep. E. Malling Res. Sta. for 1934*, **A18**, 57.

ROBERTS, R. H. (1929). "Some stock and scion observations on apple trees." *Agric. Exp. Sta. Univ. of Wisconsin Res. Bull.* **94**.
SPINKS, G. T. (1931). "Apple rootstock investigations." *Rep. agric. hort. Res. Sta. Long Ashton for 1930*, 19-26.
SWARBRICK, T. (1936). "Plum rootstock variety trial at Long Ashton, 1925-1934." *Rep. agric. hort. Res. Sta. Long Ashton for 1935*, 15-30.
TYDEMAN, H. M. (1935). "Apple rootstocks immune from Woolly Aphis. A progress report on trials with new varieties." *Rep. E. Malling Res. Sta. for 1934*, **A18**, 115-122.
——— (1937a). "Experiments on hastening the fruiting of seedling apples." *Rep. E. Malling Res. Sta. for 1936*, **A20**, 92-9.
——— (1937b). "Studies on new varieties of apple rootstocks." *Journ. Pom. and Hort. Sci.*, **15**, 165-90.
T[YDEMAN], H. M. (1937c). "Testing of Imported Wildings." *Rep. E. Malling Res. Sta. for 1936*, **A20**, 42.
VYVYAN, M. C. (1938). "Effect of stock-stem and root in some double-worked trees." *Journ. Pom. and Hort. Sci.*, **16**, 251-73.
W[ITT], A. W. (1936). "Walnuts. Propagation of varieties." *Rep. E. Malling Res. Sta. for 1935*, **A19**, 39.
WITT, A. W. and GARNER, R. J. (1931). "Peach stock trials. A progress report." *Rep. E. Malling Res. Sta. for 1928-30. (II. Supplement)*, 22-31.

A RÉSUMÉ OF THE CHERRY ROOTSTOCK INVESTIGATIONS

By N. H. GRUBB

Introduction. -Cherry rootstocks now or formerly used in England belong to three botanical species: *Prunus Avium*, the sweet cherry, Gean, Gaskin, or Mazzard; *P. Cerasus*, or "*Cerasus austera*", the acid cherry; and *P. Mahaleb*, the St. Lucie cherry. Other species have been used as rootstocks overseas, particularly certain American species, mentioned by Hedrick (1915), and *Prunus tomentosa*, said to be used in China as a rootstock for the Chinese Early cherry, *P. pseudocerasus*.

So far as the writer knows, the acid cherry and Mahaleb rootstocks used in England have always been seedlings. Seedling sweet cherry stocks are also commonly used. In addition, wild sweet cherry plants taken from woodlands are widely used by nurserymen; these may be either seedlings, or "suckers" from wild trees.

On the Continent extensive claims are made for the "Whitebarked Mazzards" raised from wild seed collected in the Harz Mountains. It is said that scion varieties worked on these produce healthy, long-lived trees.

There are also in use overseas at least two varieties of acid cherry rootstock raised vegetatively. These are the "Kentish Red" of Australia and New Zealand, raised by layering; and the "Stockton Morello" of California, said to be obtained mainly as "suckers". Sweet cherry scion varieties worked on these two stocks are considerably dwarfed.

Work on cherry rootstocks was begun at East Malling early in 1914, with small collections of all three species obtained from English and Continental trade sources. All so obtained appeared to be seedlings.

Since that time many more rootstocks have been added to those on trial, mainly seedlings of all three species raised at East Malling from seed from various sources, but including also the above mentioned vegetatively raised acid cherry stocks in use overseas, and the Wye Morello, obtained as "suckers" in Kent; the latter is not known to have been used as a rootstock. Collections of whitebarked Harz Mountain Mazzards have also recently been obtained.

Investigations on these rootstocks, already carried out, and planned for the future, follow two lines: A. The extent of the variation amongst the seedling material, and the possibilities of its elimination by vegetative propagation. B. The influence of selected clonal rootstocks on the scion varieties worked on them.

A.—Variation of Material and Vegetative Propagation.

(i) *Prunus Avium, Sweet cherry or Mazzard.*—Two reports (Grubb and Witt, 1925; Grubb, 1933) described the variation observed in seedling sweet cherry rootstocks, and also the comparative uniformity of similar rootstocks raised vegetatively. Brief notes on the work have also appeared at intervals in the Annual Report of this Station.

It has been found throughout that sweet cherry seedlings are widely variable in many of their characteristics, particularly vigour ; and that many individuals root readily from layers, some as readily as any plum stock.

Up to the present about 320 seedlings have been layered. Most of them have been discarded ; there remain on trial, with either sweet or acid cherry scions or both, nineteen selections, of which fourteen are still being propagated ; twelve more are not yet available in large enough numbers for trial. This number will be increased by any selected from two batches recently received from the Continent.

All the thirty-one selections so far made were based solely on ease of rooting from layers. Some few which appeared equally ready in rooting were discarded, usually because they seemed to be especially susceptible to attacks of black aphis.

Future Work.—There is clearly no practical need for further work on the vegetative propagation of sweet cherry rootstocks. Most of those now being propagated are as prolific of shoots, as ready rooting, and therefore as commercially practicable for propagation by layering, as most plum stocks. Other than routine observations on vigour of growth, rooting, etc., the only important work remaining to be done under this head is the observation of the variation amongst the recently acquired White-barked Harz Mazzards, and the selection of any that seem promising enough in the layer beds to warrant further trial.

(ii) *Prunus Cerasus, Acid cherry.*—One of the previous reports (Grubb, 1933) described the extreme variation observed amongst seedling acid cherry rootstocks, and the difficulty of propagating them by layering. The variation was found to be very much greater than that amongst any of the collections of sweet cherry and Mahaleb seedlings examined. None of the acid cherries so far layered has rooted as readily as the selected sweet cherries ; a few, in favourable seasons, have had from 50 to 70 per cent. of their layer shoots fairly well rooted.

Up to the present, thirty-five acid cherries, and four obtained as buds, suckers or layers, have been layered. Only six of these still remain in the layer beds ; three more are represented as rootstocks in one of the stock trial plots, and of these one is suckering freely. The four vegetative stocks are the three named varieties already mentioned, and a wild form obtained as buds near Folkestone. Twenty-five acid cherries, apparently seedlings, received from the Continent in March, 1939, will be layered in 1940. These appear so far less variable than batches of acid cherry seedlings previously examined.

Future Work.—Since it is clear that acid cherries root less readily from layers than sweet cherries, the small number so far tested obviously gave an inadequate field for selection. Of the six varieties still in the layer beds, three or perhaps four might be commercially practicable : the Australian " Kentish Red ", the Wye Morello, one of the seedlings raised at East Malling from wild seed, and perhaps the Stockton Morello. Since the " Kentish Red " is normally propagated in Australia by layering (the other two named varieties are usually obtained as suckers), and has recently given the highest proportion of rooted layer shoots (70 per cent.) ever seen in an acid cherry at East Malling, it may be the most hopeful for further work. At the same time, there is room for a trial of much larger numbers of seedling acid cherries, and perhaps of named varieties grown for their fruit. It is proposed, as soon as time allows, to raise one or two large batches of seedlings from the seed of named varieties, and to layer them all in the search for more easily propagated forms.

(iii) *Prunus Mahaleb, the St. Lucie cherry.*—The variation observed amongst seedling Mahalebs, and the difficulty of finding forms which will root readily from layers, have been described (Grubb, 1933). There was considerable variation in habit of growth and fruit character, but probably less in vigour than amongst sweet cherry seedlings.

Up to the present, eighty-nine Mahalebs have been layered. Of these, three still remain in the layer beds, and two more are represented as rootstocks in two of the stock trial plots.

Future Work.—It is clear (see below, Sect. B.) that Mahaleb rootstocks cannot at present be recommended for general use. At the same time, they have certain good points, and it is possible that when more is known about them, they may return to favour, at least for some purposes. It is proposed for the present to retain the three varieties still in the layer beds (two of which might be commercially practicable for layering, having recently had over 50 per cent. of their shoots rooted), but to discontinue the search for forms more easily propagated.

B.—The Influence of the Rootstock on the Scion.

(i) *Prunus Avium, Sweet cherry.*—Of the early sweet cherry rootstock selections, nineteen have been under trial, with either sweet or acid cherry scions or both, for from ten to eighteen years. A Progress Report on the results with acid cherry scions has been published (Grubb, 1933). Brief notes on the results with both sweet and acid cherry scions have appeared at intervals in the Annual Report of this Station.

It is clear that different sweet cherry rootstocks can influence the scion differently, in vigour, habit of growth, fruit bearing, and fruit character, and probably also in susceptibility to bacterial canker and brown rot blossom wilt. Since the basis of selection of the rootstocks under trial was solely their ease of rooting from layers, it is most unlikely that the extremes of possible influence have been found. No incompatibilities between sweet cherry rootstocks and either sweet or acid cherry scions have yet appeared.

Future Work.—There is no indication that even the oldest stock trial trees (Morello) on sweet cherry rootstocks are approaching the end of their profitable life. As they were planted too closely at 12 feet square, these oldest trees have all been "dehorned", and seem likely still to have a good many years of usefulness. Since some of the rootstocks may produce longer lived trees than others, it is proposed to continue at least a minimum of recording for several years. The younger acid cherry trees will be recorded in as much detail as time allows.

The trees of sweet cherry scion varieties are now fourteen years old from the bud, and eleven years from planting ; they are thus only beginning to reach a profitable age. It is proposed, as far as time allows, to continue recording tree size, amount of blossom and fruit, size of fruit, injury by bacterial canker, root suckering, and any other data likely to be useful.

Three small cherry stock trials have been kindly planted for us by Members on their farms. The first of these, with sweet cherry scions, suffered from uneven and scanty material and an unsatisfactory plan ; whilst the second, also with sweet cherry scions, was badly injured in its third and fourth years by "The Death". These two trials are not considered worth continuing. The third, of Morello scions on five sweet cherry rootstocks, is now seven years old from the bud. It is proposed to continue recording tree size and cropping as far as possible.

(ii) *Prunus Cerasus, Acid cherry.*—Acid cherry rootstocks have long been reputed to dwarf scions of sweet cherry. In Australia and New Zealand the "Kentish Red" stock, and in California the "Stockton Morello", are known to have this effect ; mature trees are much smaller than similar trees on sweet cherry stocks.

The difficulty of propagating acid cherries by layering has much delayed the East Malling investigations on their influence on the scion. Some of the few rooted layer shoots obtained in the early years were worked with Morello scions, and planted out with the trees on sweet cherry stocks ; they are now fifteen to eighteen years old. The results up to 1933 have been published (Grubb, 1933). The Morello scions were so much dwarfed that most of them failed to crop adequately ; but what fruit they bore was in some seasons larger than that of any trees on other stocks.

The only sweet cherry scions so far worked on acid cherry stocks at East Malling formed part of a nursery trial. Two scion varieties, Early Rivers and Frogmore, worked on two sweet cherry stocks (F2/1, vigorous, and F5/4, slightly dwarfing) and on one acid cherry stock (F4/1, obtained as suckers from some of the above mentioned trial trees of Morello), made much less growth in their first three years, and blossomed somewhat more freely, on F4/1 than on either F2/1 or F5/4. It is thus probable that the "Kentish Red" and "Stockton Morello" are not the only acid cherry stocks which will dwarf sweet cherry scions.

The commercial value for English conditions of dwarf sweet cherry trees may perhaps be questioned. It is unlikely that they could be grown in the time-honoured way, as standard trees in grass orchards. They would nevertheless reduce labour costs materially, at least in such operations as spraying and picking, and might give the added advantage of quicker cropping. It seems not unlikely that modern methods of managing apple trees in grass could be successfully adapted to cherries. Although Morello trees dwarfed by acid cherry stocks cropped poorly, it does not necessarily follow that dwarf sweet cherry trees, with their very different fruiting habit, would give a smaller yield per acre than large standard trees. The prospect is at least considered favourable enough to justify pushing on with this work as rapidly as possible.

Future Work.—One instance of incompatibility between a sweet cherry scion variety and an acid cherry stock (Chapman on Stockton Morello) has been recorded (Philp, 1930). The writer has himself found indications of incompatibility between certain scion varieties and Wye Morello stocks. The next step, therefore, is clearly to explore how far the acid cherry stocks now available are compatible with the more important sweet cherry varieties. This can be done in nursery trials, which can also be so planned as to give much information about stock influence on scion for the first three years. Field trials must follow as soon as opportunity allows.

(iii) *Prunus Mahaleb.*—Mahaleb stocks have been very widely used, especially in America. They have usually been found to produce large, good looking trees in the nursery, but eventually to dwarf the scion, at least slightly. Howe (1927), in New York State, found that many trees on Mahaleb are short lived as compared with similar trees on Mazzard ; the same has been found with Morello scions at East Malling (Grubb, 1933).

Here again the difficulty of propagation by layering has much delayed the East Malling work.

As with acid cherry stocks, some of the few rooted layer shoots were worked with Morello scions, and a few also with Kentish Red. For several years both scion varieties made large trees, but eventually both fell off in growth, and bore smaller fruit than trees on other stocks. The Morello trees, besides in some cases dying early from an unknown cause, proved more susceptible to Silver Leaf than similar trees on sweet cherry stocks. In some seasons both varieties opened their blossoms a few days earlier on Mahaleb stocks than on others.

The only sweet cherry scions so far worked on Mahaleb stocks formed part of a nursery trial. Three scion varieties, Early Rivers, Governor Wood, and Waterloo, were worked on one sweet cherry stock (F1/1), and on three selected Mahalebs, F6/1/2, F8/1/10, and F8/1/12. The buds took poorly, giving a very irregular stand ; but there seemed to be clear evidences of incompatibility, shown by early leaf colouring and defoliation, and in several cases by death of the trees, amongst those on Mahaleb, whilst no such indications appeared amongst those on F1/1.

Future Work.—Since it is obviously impossible for the present to recommend Mahaleb stocks for general use, continued work with them is not urgent. In view of a statement by Philp (1930), that there are in California large sweet cherry trees of considerable age, known to be on Mahaleb stocks, and still flourishing, it will be well eventually to explore the possibilities further. The explanation of such widely different results may be connected with either climate, soil, or the particular varieties of scion and Mahaleb stock concerned.

C.—Ornamental Cherries.

This work was undertaken because the question was repeatedly asked, whether *Prunus Avium* is a satisfactory stock for the Japanese varieties. It has been claimed that all are fully compatible with sweet cherry stocks ; but one apparent case of delayed incompatibility has been found at East Malling, between a variety received as "Prunus serrulata albo-rosea" and the sweet cherry rootstock F5/2. All other combinations so far made with sweet cherry stocks seem satisfactory up to their fourth and fifth years.

A few varieties worked on Mahaleb stocks appear to be totally incompatible. The variety Ukon on Wye Morello made small yearling trees, and thereafter survived without appreciable growth to the present time, three more years.

No further work in this direction is contemplated at present.

Summary.—An account is given of the present position and expected developments in investigations concerning cherry rootstocks belonging to three botanical species. The majority of cherry rootstocks used in England have been seedlings, which vary widely, especially those of *Prunus Cerasus*, the acid cherry. The possibility of eliminating this variation by vegetative propagation is discussed.

The prospects in English conditions of certain vegetatively raised acid cherry rootstocks, in use overseas for producing dwarf trees of sweet cherry scion varieties, are described. Known and suspected cases of incompatibility between sweet cherry scions and certain stocks are mentioned.

References

Grubb, N. H. and Witt, A. W. (1925). "Cherry Stocks : Their Behaviour in the Nursery." *Rep. East Malling Res. Sta. for* 1924, 87-92.

Grubb, N. H. (1933). "Cherry Stocks at East Malling. I. Stocks for Morello cherries." *Journ. Pom. and Hort. Sci.*, **11**, 276-304.

Hedrick, U. P. (1915). "The Cherries of New York." *Rep. N.Y. agr. Exp. Sta.*, 1915, **74**.

Howe, G. H. (1927). "Mazzard and Mahaleb Rootstocks for Cherries." *N.Y. agr. Exp. Sta. Bull.* **544**.

Philp, G. L. (1930). "Cherry Culture in California." *Cal. agr. Extension Service, Circ.* **46**, 20-2.

APPLE ROOTSTOCKS IMMUNE FROM WOOLLY APHIS

II. THE TESTING IN THE NURSERY OF NEW SEEDLING IMMUNES

By H. M. TYDEMAN

Reports on the work carried out jointly by the John Innes Horticultural Institution and the East Malling Research Station since 1921 on raising apple rootstocks combining immunity to attack from Woolly Aphis with good performance pomologically, have been issued periodically (see list of references). There are now under test about 800 seedlings showing great resistance, and further breeding work along the original lines is being suspended until greater progress has been made in assessing the pomological value of the existing material and in determining how far the objects of the original scheme of work have been achieved.

For the pomologist, the testing of these seedlings falls into two phases : (1) the initial testing for ease of rooting and the ability to produce numerous clean vigorous shoots, when stooled, and (2) testing their value as rootstocks when worked with scion varieties.

It has been the custom hitherto to subject all those seedlings whose immunity from Woolly Aphis has been definitely established, to a period of several years in the nursery as stools. The rooting, vigour and feathering of the annual growths are carefully noted, together with the principal botanical characters and outstanding instances of susceptibility to fungus diseases.

The results of such tests on 566 individuals from twenty different crossings are summarized in the Table. Although all the seedlings were not growing under exactly similar conditions and were not of the same age, the figures are sufficiently accurate for the purposes of a rough comparison.

TABLE SHOWING DETAILS OF BEHAVIOUR IN THE STOOL BEDS

Parentage.	Number of Seedlings.	Av. No. of Shoots per Stool.	Vigour of Shoots.			Rooting of Shoots.			No. of Stools with Clean Shoots.
			Strong.	Medium.	Weak.	Good.	Fair.	Poor.	
Northern Spy × Malling No. I ..	64	5·2	36	16	12	22	19	23	40
Malling No. I × Northern Spy ..	45	7·9	19	16	10	1	22	22	31
Northern Spy × Malling No. II ..	92	9·8	59	27	6	15	28	49	61
Malling No. II × Northern Spy ..	82	11·6	47	33	2	4	27	51	34
Northern Spy × Malling No. VIII	5	7·0	3	1	1	1	1	3	3
Northern Spy × Malling No. XII	26	7·3	19	7	0	1	14	11	11
Northern Spy × Malling No. XV	3	2·7	3	0	0	3	0	0	1
Malling No. XV × Northern Spy	7	3·4	0	1	6	4	2	1	7
Bristol O.F.5 × Northern Spy ..	57	6·9	53	3	1	0	1	56	13
Northern Spy × Merton 789* ..	26	5·9	12	5	9	6	4	16	20
Northern Spy × Merton 793 ..	24	5·5	10	9	5	10	8	6	17
Merton 793 × Northern Spy ..	13	5·3	8	4	1	1	6	6	10
Merton 789 × Merton 793 ..	6	7·2	3	3	0	0	1	5	1
Merton 793 × Merton 789 ..	25	6·2	5	16	4	0	1	24	17
Northern Spy × Winter Majetin	32	4·7	32	0	0	7	6	19	0
Northern Spy × Trans. de Croncels	6	3·3	5	1	0	0	0	6	2
Northern Spy × R. Zuccamaglio	14	4·6	12	2	0	2	2	10	5
R. Zuccamaglio × Northern Spy	13	5·2	13	0	0	0	4	9	1
Northern Spy × Ben Davis ..	22	6·1	22	0	0	0	6	16	12
Northern Spy × Jonathan ..	4	3·8	0	2	2	1	2	1	4

* Merton Nos. 789 and 793 are selections from No. II × Northern Spy.

It will be noted that of the five varieties of " Paradise " apple used in crosses with Northern Spy, No. II gave the largest proportion of seedlings making vigorous and prolific stools, but more of the stools had well-rooted shoots in the crosses Spy × No. I and Spy × No. XV. The seedlings from crosses between Spy and the Merton immunes Nos. 789 and 793 (themselves immune seedlings from No. II × Spy), were less vigorous or prolific but contained rather more good rooters than the parent cross. Intercrossing these Merton immunes produced seedlings making decidedly less vigorous but more prolific stools than where they were crossed with Spy, but they were almost entirely poor rooters. Seedlings from crosses between Spy and the highly resistant varieties Winter Majetin, Transparent de Croncels, Reinette Zuccamaglio, Ben Davis and Jonathan made rather poor rootstocks in the nursery. Spy × Winter Majetin seems to be the most promising of these combinations so far found. All the stools were vigorous and more than 20 per cent. had well-rooted shoots.

Tests such as this would form a useful basis upon which to eliminate all but the most promising individuals. Thus, of the 566 seedlings whose performance is summarized in the Table, only 78, or 14 per cent., were really well rooted by ordinary nursery standards, and although some of the remaining seedlings might become better rooting in course of time, as occurred in the case of Malling Nos. II and XII, it is unlikely that they would ever equal those which have rooted well in their earlier years. If, however, all but the seventy-eight good rooting individuals were discarded there would be a real danger of losing many seedlings of good potential performance as rootstocks particularly if, as seems conceivable, the capacity to root well were linked in inheritance with some rootstock characteristic such as extreme " dwarfingness " or precocity.

For this reason, it has been thought the safest course to pass as many of these seedlings as possible through the further trials designed to discover their influence on the scion, regardless of their performance in the propagation tests. Some 250 of them have been grafted with Lane's Prince Albert on the stools. The grafts were inserted on to the shoots of the previous year's wood and left to grow for a

year on the stools. Four trees from each stool were then removed and planted out in nursery rows at 7 feet by 3 feet apart. There were relatively few graft failures on the stools and, although rooting was frequently poor, due to a tendency on the part of the grafted shoots to rely on the main stool root system, all but a few of the trees lived when planted out and, in their second season, are making satisfactory growth. Such a method saves much time, but its chief drawback is that only a few trees on any one rootstock can be obtained owing to the limited and variable number of shoots on a single stool. However, as a rapid method of testing the compatibility of such rootstocks with particular scions or of obtaining an approximate idea of their influence on the scion it has much to recommend it. Selections for further more extensive trial can be made based on the results of such a preliminary test.

The more usual practice has been to raise sufficient rootstocks from each of these seedlings to make a fairly large unit of trees when worked with the scion. Ten-foot lengths of propagation bed are formed for each seedling, the stools being extended as material becomes available. The shoots are severed from the stools and planted out in nursery rows for a year before being worked with the scion. Such a method, while unquestionably more accurate and reliable, is also much more laborious and slow in yielding results.

Acknowledgements.—This work has been carried out in close association with the Propagation Section, and the writer gratefully acknowledges the collaboration of Messrs. R. J. Garner and D. H. Hammond from the practical side.

Summary.—Apple rootstocks which have been proved to be highly resistant to attack by Woolly Aphis have been tested for their pomological characters.

In nursery trials with 566 such rootstocks considerable differences are indicated in the performance of families of diverse parentage under propagation tests.

An account is given of various methods for discovering the influence on the scion of these rootstocks.

References

Crane, M. B., Greenslade, R. M., Massee, A. M. and Tydeman, H. M. (1936). "Studies on the Resistance and Immunity of Apples to the Woolly Aphis." *Journ. Pom. and Hort Sci.*, **14**, 137-63.

Crane, M. B., Greenslade, R. M., Hatton, R. G., Massee, A. M., Roach, W. A., Rogers, W. S. and Tydeman, H. M. (1937). "Problems raised by the Woolly Aphis of the Apple." *Ann. appl. Biol.*, **24**, 169-210.

Le Pelley, R. H. (1927). "Studies on the Resistance of Apple to the Woolly Aphis." *Journ. Pom. and Hort. Sci.*, **6**, 209-41.

Massee, A. M. (1931). "The Resistance of Certain Apple Stocks to Attacks of the Woolly Aphis." *Rep. E. Malling Res. Sta. for 1928-30* (II. *Supplement*), 202-5.

Staniland, L. N. (1923, 1924). "The Immunity of Apple Stocks from Attacks of Woolly Aphis." Part I. *Journ. Pom. and Hort. Sci.*, **3**, 85-95. Part II. *Bull. Ent. Res.*, **15**, 157-70.

Tydeman, H. M. (1935). "Apple Rootstocks Immune from Woolly Aphis. A Progress Report on Trials with New Varieties." *Rep. E. Malling Res. Sta. for 1934*, 115-22.

APPLE ROOTSTOCKS IMMUNE FROM WOOLLY APHIS

III. THE INFLUENCE OF FOUR NEW SEEDLING IMMUNES ON LANE'S PRINCE ALBERT

By H. M. TYDEMAN

Of some 800 apple seedlings which have been raised and found to be very highly resistant to attack by Woolly Aphis, only four have, so far, been subjected to trial for a sufficient period to give any indication of their potentialities as rootstocks. These are the four Merton immunes Nos. 778, 779, 789 and 793, raised in 1920, by Mr. M. B. Crane at the John Innes Horticultural Institution, from Malling No. II × Northern Spy. Trials have been carried out since 1930 with these stocks, budded with Lane's Prince Albert, and the results published (Tydeman, 1934, 1935). These preliminary trials were of great value in suggesting improvements in technique, but they were difficult to interpret owing to the small units of trees, lack of standard rootstock varieties, as controls, and faulty experimental design.

It was not until the winter of 1935 that a set of maiden trees of Lane's Prince Albert on all four Merton immunes, on Malling Nos. IX, II and XII, and on Northern Spy were available. They were lifted from the nursery, planted out in randomized blocks in units of three trees, at 5 feet by $2\frac{1}{2}$ feet

apart, supported by wires and allowed to grow naturally without pruning. The length of new wood, girth of trunk, number of blossom trusses, number and weight of fruits, have been recorded annually together with other observations of a more general character. At the end of their fifth year they have reached a period when it is possible to review the first stage of their development.

(*a*) *Relative Vigour as expressed by Length of New Wood Growth.*—Records of the length of new wood growth made annually are summarized in Table I. All four of these immunes have proved to be more vigorous in their influence on the scion than either of their parents, No. II or Northern Spy, in their early years. While there is a considerable difference in the length of wood growth made

Table I.

Average Annual New Wood Growth Per Tree. In One-tenths of a Metre.

	Number of trees.	Five years' total.		Number of trees.	Five years' total.
Merton 778	39	202	Malling No. IX	30	119
Merton 779	36	242	Malling No. II	34	163
Merton 793	36	242	Northern Spy	24	169
Merton 789	43	254	Malling No. XII	15	304

between trees on No. 778 and No. 789, it is not nearly so great as that between trees on No. II and No. XII. Although Lane's on No. 778 has proved to be rather less vigorous in this, than in earlier trials, the position of these stocks between No. II and No. XII in the comparative order of vigour of the " Paradise " series, has proved to be similar to that found in earlier trials. That trees on these four rootstocks do not differ markedly in vigour among themselves is also a confirmation of results previously obtained. For instance, Lane's on three of these rootstocks growing in an earlier trial produced the following average length of new wood during their eighth year :

Merton No. 778 : 2,679 cm.
Merton No. 793 : 2,259 cm.
Merton No. 789 : 3,083 cm.

Although a complete statistical analysis of the data has not been undertaken at this stage, the indications are that these four Merton immunes should be placed within a single group, as being much more vigorous than either parent but not so vigorous as the stronger growing of the Malling series. It is evident that immune rootstocks, some much more vigorous and others much more dwarfing, are required if a series of immune rootstocks covering the same range of vigour as the Malling series is to be obtained.

(*b*) *Relative Fruitfulness as expressed by Blossom Production.*—Of the two measures of fruitfulness, it is probable that number of blossoms is a more reliable criterion than number or weight of fruit, since the latter may be greatly affected by the weather at blossoming, or pests such as apple blossom weevil. In Table II is shown the number of blossom trusses borne by these trees during their first six years.

Table II.

Average Number of Blossom Trusses Per Tree.

	Number of trees.	Second Year.	Third Year.	Fourth Year.	Fifth Year.	Sixth Year.	Six Years' total.
Merton 778	39	0·1	28	45	146	173	392
Merton 779	36	0·0	31	63	178	205	477
Merton 793	36	0·5	29	61	164	230	484
Merton 789	43	0·0	33	49	169	214	465
Malling No. IX	30	6·6	22	106	112	139	385
Malling No. II	34	2·0	31	75	112	192	412
Northern Spy	24	0·6	17	60	108	164	350
Malling No. XII	15	0·0	14	21	121	174	330

The most prolific of the four immunes was No. 793 with a total of 484 blossom trusses, while No. 778 was the least prolific. With the exception of No. 778, trees on which had fewer blossoms than those on Malling No. II in all but one of the six years, all these immunes have produced more blossoms per tree than either of their parents. They have also exceeded trees on No. IX in this respect. However, to give an accurate picture of the productivity of the trees, the figures for blossom production

have to be related to the area of potential bearing wood. The following are the average number of blossom trusses per tree in the spring of 1940 per metre of new wood in 1939 :

Malling No. IX ..	272	Merton Immune No. 778 ..	55
Malling No. II ..	90	Merton Immune No. 779 ..	51
Northern Spy ..	68	Merton Immune No. 793 ..	57
Malling No. XII ..	27	Merton Immune No. 789 ..	54

Hence it will be seen that, on the basis of potential fruiting area, trees on Malling No. IX were far the most prolific and those on Malling No. II and on Spy were more prolific than any of the Merton immunes. These immunes do not appear to differ significantly among themselves. It is interesting that trees on all four, belonging to a definitely more vigorous group than those on either parent, should also be less prolific in their earlier years.

(*c*) *Relative Fruitfulness as expressed by Cropping.*—These trees have produced little fruit so far. Although they bore some blossom in the spring following transplanting, no fruit matured. They yielded a little fruit in the two seasons following, but their first appreciable crop did not come until their fifth year. The average weight of fruit per tree from the third until the fifth year is shown in Table III.

Table III.

Average Weight of Fruit Per Tree in Lbs.

	Number of trees.	Five years' total.		Number of trees.	Five years' total.
Merton 778	39	1·5	Malling No. IX	30	3·5
Merton 779	36	1·9	Malling No. II	34	1·9
Merton 793	36	2·2	Northern Spy	24	1·1
Merton 789	43	2·0	Malling No. XII	15	0·8

As might have been expected, trees on No. IX bore more fruit in the earlier years than those on any other rootstock, while those on No. XII bore the least. With the exception of those on No. 778, trees on all the immunes cropped more heavily than those on either No. II or Spy. The differences are scarcely great enough to be significant, however, and, as with blossom production, are probably entirely the result of differences in tree size. Trees on No. IX set the largest crop in their fifth year, in spite of the smaller number of blossoms. This was partly due to the slightly larger fruits borne by trees on this stock but there are also indications that there was a better set of flowers.

Some years must elapse before the full story of the cropping of the trees on these immune rootstocks can be told.

Acknowledgements. –The writer's best thanks are due to the numerous workers in the Pomology Section, particularly Miss A. B. Beakbane and her assistants, who have helped him with the recording of these trials from time to time.

Summary.—In the first five years, trees of Lane's Prince Albert on the four Merton immune rootstocks, Nos. 778, 779, 789 and 793 (Malling No. II × Northern Spy) have been found to be very similar in their performance and to be somewhat more vigorous but less precocious than either of their parents.

References

Tydeman, H. M. (1934). "The Testing of New Varieties of Apple Rootstock. A Progress Report." *Rep. E. Malling Res. Sta. for 1933*, 94-9.

——·– (1935). "Apple Rootstocks Immune from Woolly Aphis. A Progress Report on Trials with New Varieties." *Rep. E. Malling Res. Sta. for 1934*, 115-22.

WEATHER CONDITIONS DURING 1939

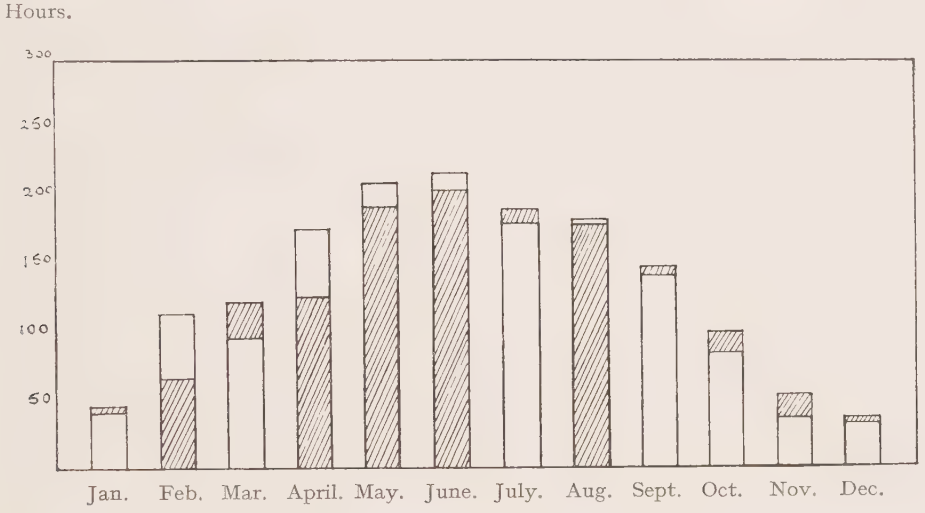
By H. C. CHAPELOW and H. M. TYDEMAN

From the horticulturist's point of view the weather conditions during the past year were very satisfactory. Although the aggregate rainfall was exceptionally high, seven inches above the normal, the excess fell during the very early and late seasons of the year when it caused little interruption to work on the land. All varieties of fruit blossomed under ideal conditions without damaging frosts, and excellent crops were obtained.

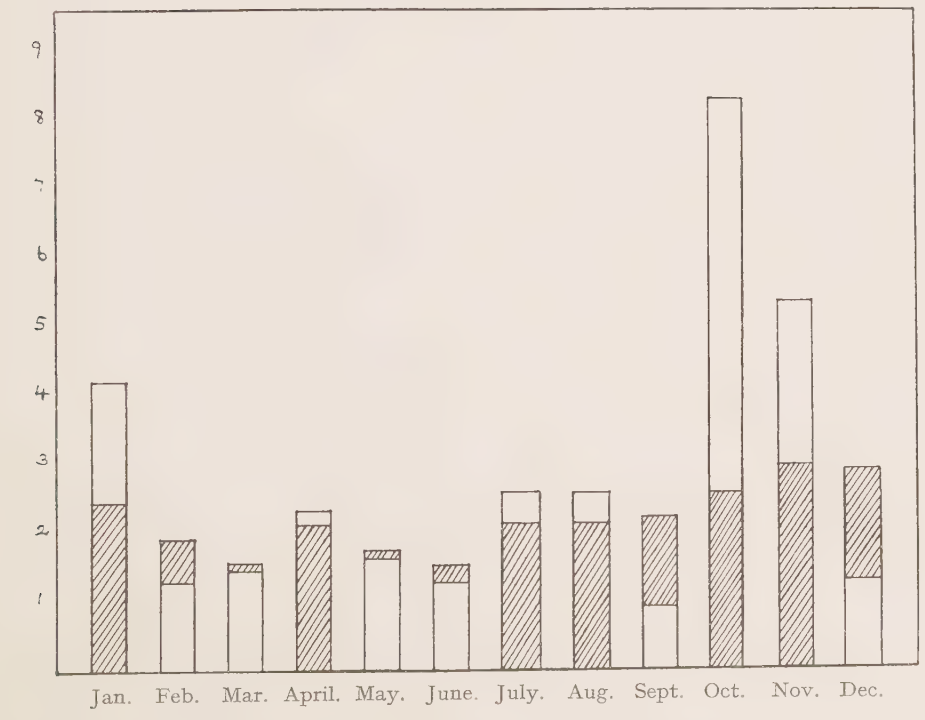
The total rainfall for the year was thirty-three inches, just seven inches in excess of the twenty-four years' average here. The distribution of the rainfall through the year was very exceptional. Actually,

more than half the year's rainfall occurred during the three months January, October and November, while September and December were unusually dry with less than half the normal rainfall. The sun shone for 1,528 hours, about 50 hours more than the twenty-four years' average at this Station. Sunshine was considerably deficient during the early spring and late autumn but was otherwise fairly average. Temperature followed an approximately usual course through the year, although the summer months from May till August were somewhat cooler than is normal.

TOTAL SUNSHINE IN HOURS



TOTAL RAINFALL IN INCHES



Diagrams showing Total Sunshine and Rainfall during 1939 as compared with 24 years' average.
Shaded portion 24 years' average.

SUMMARY OF METEOROLOGICAL OBSERVATIONS DURING 1939.

	Temperature in Screen.					No. of Ground Frosts.	Rainfall.			Sunshine.			Soil Temperature.		
	Mean Maximum.	Mean Minimum.	Highest.	Lowest.	Mean.		Total in inches.	Heaviest fall in a day.	24 years' average.	Total hours.	Average per day.	24 years' average.	4 inches.	8 inches.	2 feet.
January ..	46	37	55	23	42	11	4·18	0·95	2·42	42·1	1·4	47·2	39·0	36·2	40·7
February ..	49	35	59	23	42	14	1·27	0·44	1·90	114·0	4·1	68·5	37·7	39·0	40·8
March ..	52	36	57	27	44	11	1·42	0·25	1·52	97·7	3·1	121·0	40·0	40·6	42·4
April ..	57	39	74	30	48	9	2·32	0·51	2·09	177·8	5·9	127·7	46·8	47·0	47·9
May ..	61	42	74	31	52	1	1·63	0·85	1·74	210·8	6·8	193·7	53·3	52·3	52·5
June ..	66	48	82	36	57	0	1·27	0·30	1·52	217·7	7·2	203·7	58·8	55·2	53·9
July ..	69	52	78	39	60	0	2·57	0·60	2·12	181·4	5·9	191·5	61·8	61·1	61·7
August ..	71	52	80	42	61	0	2·55	1·47	2·16	184·8	6·0	182·7	62·8	63·1	63·2
September..	67	50	82	34	58	0	0·90	0·33	2·20	143·4	4·8	148·9	59·3	60·1	62·3
October ..	55	41	63	26	48	4	8·31	1·53	2·50	85·7	2·8	101·4	47·2	48·3	52·1
November ..	54	42	59	28	48	2	5·27	0·58	2·95	39·0	1·3	53·9	45·7	46·5	48·0
December ..	42	32	55	12	37	12	1·27	0·42	2·85	33·5	1·1	38·3	36·2	38·9	42·4
Totals ..						64	32·96		25·97	1527·9		1478·5			

BIOCHEMISTRY

DIAGNOSIS OF MINERAL DEFICIENCIES AND EXCESSES BY SYSTEMATIC LEAF INJECTION AND ANALYSIS

By W. A. ROACH

Introduction.—The system evolved at East Malling Research Station for studying the mineral nutrition of plants is based on the fact that a satisfactory supply of minerals in the leaf is essential for the health of the whole plant because it is there that the raw materials of the general metabolism of the plant are synthesized. The minerals actually present can be ascertained by analysis of the plants, and their adequacy can be tested by watching the effect of introducing supplementary amounts of the minerals one or more at a time.

The effects of rootstock, soil type, and of artificial manures, have so much in common as to suggest that an investigation of their effects on the mineral nutrition of plants by the above system would throw much light on these and other problems. This is a large field of work, and the investigation has been planned in a series of stages, each with a result of practical value as its immediate aim. This system, although capable of considerable further development, has already been used for making a survey of the mineral status of plants in the area of deciduous fruit trees of South Africa, which led to far-reaching conclusions both of a practical and theoretical nature. It can now be used both to increase crop production, and to effect economies in the use of artificial manures.

Injection.—Injection methods already developed and published (Roach, 1938) enable us to introduce liquid at will into a selected part of a plant as small as a single interveinal area or as large as a main branch or a whole tree. By injecting minerals one or more at a time and observing their effects, mineral deficiencies can be diagnosed extremely rapidly (two to seven days in England, fourteen days in South Africa). The responses take the form of increased growth (sometimes resulting in a puckering of the treated parts of leaves), and improvements in leaf colour and in what in the animal would be called " condition " and in the human being complexion. The methods owe their extreme sensitivity to the fact that treated and untreated leaf parts are separated from each other by a vein only, their sensitivity therefore approaching that of optical " divided field " methods.

Preliminary Work.—In the course of the extensive work necessary to control the movements of injected liquids, in establishing among others the fact that minerals have the same effects on the plant when injected as when absorbed naturally, a number of encouraging results were obtained, some of which will be described briefly.

Preliminary Results.—1. After injection with potassium nitrate an apple tree bearing thin leaves of poor colour put out thick leaves of outstandingly healthy colour ; this result was the more striking because the foliage, though of an unhealthy metallic green, did not show any symptom specific for any particular mineral deficiency. Measurements showed that, though in previous years shoot extension growth had been declining, this year it exceeded the previous year's growth by 75, 60 and 50 per cent. in the various branches, corresponding with the uneven distribution of these early experiments (Roach, 1934).

2. The cause of a disease of apples, the symptoms of which are known under a number of names, including corky core, was diagnosed by injection experiments, using Roach's methods, almost simultaneously in New Zealand by Atkinson (1935), in Canada by McLarty (1936), in the U.S.A. by Young and Bailey (1936), and in Finland by Jamalainen (1936), as a boron deficiency. On most soils it has been cured by applications to the soil ; on others soil applications are ineffective but an economic cure is possible by injection. Thus at very little expense injection methods provided in two years an economic solution of the most serious transport trouble of apples grown in Canada and New Zealand.

3. Teakle (1937) using Roach's injection methods showed that a serious die-back disease of pines in Australia was due to copper deficiency, and Dunne (1938) proved that injection, sprays and soil applications were effective against " wither tip " of apples in Western Australia.

4. Commercial apple trees of average health and vigour after injection with dipotassium hydrogen phosphate and urea, each at the rate of about 28 lb. per acre, made twice as much shoot growth as untreated trees and the leaves were thicker and of a markedly more healthy green colour (Roach, 1935).

Resistance to Insect Pests.—The injected trees were free from Red Spider and Leaf Hopper, in marked contrast to the heavily infected untreated trees (Roach, 1935). A similar result has since been obtained with Rosy Apple Aphis.

Resistance to Fungus Attack.—5. Injection of sodium thiosulphate made apple shoots resistant to attack by Apple Mildew, untreated shoots being heavily infected (Roach, 1934).

6. Plum trees suffering from severe attacks of Silver Leaf have recovered, following injection either with 8-hydroxyquinoline potassium sulphate or with a complete nutrient solution (K_2HPO_4 + urea).

Work in South Africa.—A recent visit to South Africa provided an invaluable opportunity for testing these combined methods on plants varying more widely in mineral status than any in this country. At this time the injection methods were ready for routine use in the field and the valuable results obtained on the extremely variable South African material have helped to explain results already obtained in England and has expedited the application of the methods.

Injection Results Confirmed by Manurial Experiments and Practical Experience.—The methods were used in South Africa to make a mineral status survey of the fruit trees of the Western Cape Province ; part of the experimental material was selected by Prof. M. S. du Toit to be representative of the deciduous fruit of the whole Western Cape Province and so that the results of the injection experiments could be compared with those of Prof. du Toit's manurial experiments and checked by the practical experience of the growers. Solutions of the elements mentioned later were injected in quadruplicate into leaves on about forty plants.

Injection Results in South Africa.—The results of 1,175 injections are collected in the following table, which shows the percentage of beneficial responses for each element tested.

Validity of Results. -The success of diagnostic injections must obviously depend on introducing enough of the mineral to produce an effect without causing injury. Both volume and concentration of the solution were determined empirically for each substance on each type of plant material before carrying out routine tests. The interpretation of positive results presents little difficulty ; an improvement resulting from increasing the amount of an element obviously proves that there was a deficiency of it. Although in theory negative results may be due to either a faulty choice of amount of substance, or to there being enough of it already present, in practice, the failure of suitably planned injections carried out in quadruplicate to give a beneficial response can be looked upon as suggesting that there is no deficiency of the mineral.

	Element	injected as :	No. of Injections.	% Beneficial Responses.
N.	Nitrogen	Urea	133	26
P.	Phosphorus	Sodium dihydrogen phosphate	115	14
K.	Potassium	Potassium chloride *or* Potassium sulphate	129	14
Ca.	Calcium	Calcium chloride	129	12
Mg.	Magnesium	Magnesium sulphate *or* Magnesium chloride	96	15
Zn.	Zinc	Zinc sulphate	142	23
Fe.	Iron	Ferrous sulphate	109	27
Mn.	Manganese	Manganese chloride	92	23
Cu.	Copper	Copper sulphate	69	4
B.	Boron	Boric acid	83	4
Ni.	Nickel	Nickel chloride	40	12
Co.	Cobalt	Cobalt chloride	38	9

N, P, K.—The results for nitrogen, phosphorus and potassium and the degree of response to each are in harmony with Prof. du Toit's conclusion that the former very serious deficiency of phosphorus and less serious deficiency of potassium have in large measure been made good, and that now nitrogen deficiency is more general than that of phosphorus and potassium.

Mg.—The response to magnesium (15 per cent.) is not surprising in view of the lightness of most of the soils, their poorness in organic matter, and the heavy leaching to be expected from the concentrated rainfall. Injection responses to this element had already been obtained by the writer in England and evidence of its deficiency here is increasing.

Zn.—The responses to zinc (23 per cent.) were more striking than those to the three major elements, nitrogen, phosphorus and potassium. These results were in harmony with the scattered and unpredictable good effects of commercial zinc sprays, and proved that these beneficial effects were the result of making good a deficiency of this essential element. The methods adopted provided a cheap, rapid and reliable means of detecting this deficiency.

The main value of the results so far considered is that they prove that injection may be relied on to give diagnoses of practical value. The methods also yielded results which have given quite a new picture of nutritional conditions in South Africa ; the most important is the demonstration of a widespread deficiency of manganese (23 per cent. response). In fact, of the deficiencies found in South Africa, that of manganese was the most serious economically.

Mn. - Manganese Deficiency in Peach Trees.—A severe chlorosis in peach trees, the worst of which had gone out of bearing, was proved by leaf-stalk injection to be due to manganese deficiency. Some hundreds of these trees were injected late in the South African summer of 1938-9, by "Cape coloured" labour supervised by the grower at a total cost of 2d. per tree. Although these injections were not

done until late in the summer, the few leaves which expanded afterwards were, by the end of the season, a rich dark green, in striking contrast to the other leaves in the plantation.

Commercial Cure by Injection.—The following season the foliage of the injected trees appeared to be perfectly healthy and could be identified from a distance, and later those trees bore a full crop, worth, in a normal season, £2 to £5 per tree. The successful use of " coloured " labour shows that curative injection on a commercial scale is practicable, and that highly skilled labour is not essential.

Commercial Importance of Incipient Chlorosis.—A single row of peach trees in these orchards epitomized conditions in South Africa. The row stretched from the hillside, where the soil was poor in organic matter, to the valley bottom where it was rich. The trees at the bottom appeared to be in nearly perfect health and there was a gradual decrease in depth of green, up the hillside, until at the top the trees were practically without green colour. Similarly the crop decreased from a full one at the bottom to nothing at the top. There was an obvious decrease in crop before the appearance of any yellow patches on the leaves ; there was, however, a definite decrease in the depth and quality of the green colour and a tendency for the spaces between the veins to be lighter than the tissues bordering the veins. This condition of incipient chlorosis, therefore, is one of great commercial importance, and it was common in South Africa.

Manganese Hydroxide Spray.—Although injection provides an economic cure for this deficiency it is not necessarily the best. Trees in the same plantations regained apparently perfect health after they had been sprayed with manganese hydroxide during the winter, at a cost of 6d. per tree.

Fe.—Iron deficiency (27 per cent.) was about as widespread as that of manganese. Deficiencies of zinc, manganese and iron occur under similar soil conditions, often in the same plantations.

Availability of Manganese and Iron. Soil Conditions.—These deficiencies tend to occur where soil organic matter is low, on soils that had been treated with calcium carbonate (calcium hydroxide was even more harmful in this respect), and where excessive quantities of phosphates had been applied. The most severe cases of deficiency of manganese and iron occur on soils actually containing large amounts of these two elements. The question of availability is therefore of primary importance.

Soil Test for Availability of Iron.—The availability of iron was studied in a preliminary manner by shaking the soil with a saturated alcoholic solution of ammonium thiocyanate as in the Comber test for acidity. No case of iron, manganese, or zinc deficiency was detected by injection of plants growing in any soil giving a red colour by this test ; and the only soils which both supported healthy trees and gave no red colour with this test were rich in organic matter.

Leaf injection has therefore opened up a large field of work on soil conditions which control the availability of these elements already seen to be of major economic importance in South Africa.

Iron Deficiency in England.—Results obtained in England, when considered in the light of these experiences, lead to the same general conclusions. An orchard on the ragstone showed a serious chlorosis and was going out of bearing. Iron deficiency was diagnosed by leaf injection and a few trees were cured by whole tree injection. After tuition, first by the writer and later by one of the County Officers (Mr. Duggan), the grower himself has dealt with all affected trees and from his point of view the practical problem is solved.

Frost Resistance Induced by Iron Injection.—After the severe late frost of 1938 untreated trees in this plantation bore no fruit but the injected trees bore a valuable crop. This suggests that frost resistance can sometimes be increased by improving mineral nutrition.

There have been many other instances of extreme iron deficiency in this country ; Wallace has described examples in trees growing on calcareous soils.

Incipient Chlorosis in England.—Less severe manifestations of the trouble have been recognized by leaf injection on many trees in the Research Station plantations and at a number of places in Kent and the Eastern counties, but incipient chlorosis has not as yet received the attention its economic importance deserves. Evidence of manganese deficiency in England is also accumulating, and one beneficial response to zinc spray has recently been observed in the Research Station plantations* (Moore 1940).

South African Results and English Conditions. These deficiencies in England resemble those in South Africa in that they occur mainly on soils of nearly neutral or alkaline reactions and are rarely found on soils rich in organic matter unless there is also present a large amount of calcium carbonate or phosphate. The decreasing use in recent years of horse manure, farmyard manure, etc., means that less organic matter is being supplied, and the increase in " clean cultivation " means that reserves of organic matter in the soil are being depleted, and all these factors tend towards making the above

* Since going to press zinc deficiency has been diagnosed by injection in three of the Research Station plantations and in a commercial plantation also in Kent. One of the responses to zinc injection was obtained in the set of trees used by Moore. In his experiments spraying Cox's Orange Pippin apple trees with " zinc-lime " or with a proprietary zinc preparation was followed by a marked improvement in size and colour of the leaves.

three elements unavailable. The heavy dressings of calcium carbonate applied with apparent impunity in the past to soils rich in organic matter may well be dangerous in soils now becoming progressively poorer in organic matter. These conditions are probably aggravated by large phosphatic dressings. Experience in South Africa reinforced the conclusion already arrived at that the widespread incipient chlorosis in this country is of real economic importance.

Ca.—Calcium Deficiency in South Africa.—The fact that 12 per cent. of the leaves injected with calcium chloride in South Africa gave a beneficial response indicated a widespread nutritional shortage of calcium.

Calcium Deficiency in England.—A nutritional deficiency of calcium had already been established in apple trees in a similar manner by Roach in the Tamar valley, Devonshire.

Thus calcium deficiency in fruit trees has been established both in South Africa and England. Although these are the first demonstrations in these two countries it is well known in America. No other calcium injections have so far been carried out in this country in the field but the widespread belief amongst growers that lime is necessary for the " stoning " of all stone fruits seems worth testing by these methods. They make possible a study of the effect of " liming " on the nutrition of the tree apart from its indirect effects on acidity, soil structure, base exchange, etc.

Cu, Ni, Co.—The small responses to copper, nickel and cobalt will be followed up but need not be considered further here.

B.—The " Corky " symptoms characteristic of boron deficiency have not been seen by Roach in apple fruits either in South Africa or in England. The significance of the slight response of the leaves to boron requires further investigation.

These results therefore prove that any practical advice in the field on mineral nutrition should take into account at least the essential elements : nitrogen, phosphorus, potassium, calcium, magnesium, zinc, iron and manganese. To these may have to be added copper, boron, and possibly others such as molybdenum, sulphur, silicon, nickel and cobalt.

Mineral Analysis of Plant Parts.—*Purposes.*—Analytical methods are being developed and used for six main purposes :

1. As a guide to plant injection.

Analysis was first used to ascertain what elements are actually present in plants. Next it was used to determine the mineral composition and degree of variation in composition of healthy plants of various sorts, and to determine in what respects the unhealthy plants differ from the healthy plants.

2. In the study of the effects of high concentrations of minerals, for which injection methods are not quite adequate.

It does not follow that, because the increase of a given element (for example by injection) produces no visible improvement in the appearance of the foliage, there is sufficient present for the economic end in view. For example, potassium salts are largely used in tomato growing to promote flower formation and the setting of fruit, the amounts used being greatly in excess of those required for maximum leaf production.

3. For testing the adequacy of minerals having functions other than photosynthetic. Perhaps the best example is afforded by boron, deficiency symptoms of which are most commonly seen in the apple fruit and not in the leaf.

4. For use late in the season when plant injection gives no response.

5. For studying trees which for any reason cannot be injected but from which samples can be taken, stored and analysed at leisure.

6. For the recognition of excesses of minerals. Such work should lead to economies in the application of artificial manures.

Leaf Analysis.—The visit to South Africa was as valuable for testing leaf analysis as for testing leaf injection, but in regard to leaf analysis a choice had to be made between using a single existing spectrographic method with its known shortcomings to get preliminary information, and developing further methods before applying them. In view of the unique opportunity the method was used without further development. This was the more necessary because increasing use was then being made of Thompson's services by the County Advisory Officers for the diagnosis of mineral deficiency. The results obtained here and in South Africa have justified this choice and indicated the most urgent improvements in methods, some of which have already been made. The methods will be described on page 56.

Healthy Leaves as Standards of Reference.—Healthy leaves were obtained from trees growing under as widely differing soil and climatic conditions as possible both here and in South Africa. These were sent to Thompson who examined them spectrographically in comparison with healthy leaves of the same type gathered in England and with unhealthy leaves from both places. His conclusions are, that in respect to at least the elements potassium, sodium, calcium, iron, manganese, magnesium and copper, the differences between healthy leaves of different species of deciduous trees growing under

widely different conditions are small compared with the differences frequently obtained between healthy and unhealthy leaves of the same variety growing in the same plantation.

Thus the mineral composition of healthy leaves, at least of the same species, tends towards a common standard to which the composition of unhealthy leaves can be referred. Leaves collected in South Africa by Roach and sent by air mail to Thompson were analysed spectrographically, and the results were cabled to Roach in time for him to use them in conjunction with the injection results and any field data available. Not only was the utility of leaf analysis established, but even at this early stage the results suggested lines for injection and other work.

The following four examples quoted with Major Thompson's permission, which are typical of England and South Africa, will make clear the type of result already obtained by this limited kind of leaf analysis and will indicate the further possibilities of a more complete scheme.

Case 1. *Cherries, Sittingbourne.*—Large areas of valuable mature cherries in the Sittingbourne area suffer from a chlorosis which increases in severity ; at first the crop diminishes and finally trees fail to crop. As a full crop may be worth £100 or more per acre the economic results are serious. In the late summer of 1938 a qualitative analysis was made of leaves from affected trees ; the deduction was that manganese and possibly iron were deficient, and in consequence diagnostic injections of manganese and iron were made by a County Advisory Officer (Mr. Duggan) very late in the growing season of 1938 ; no results were observed in 1938 but in the early summer of 1939 the branches injected with manganese in 1938 showed a dark healthy green standing out conspicuously from the rest of the tree and there was considerable extension growth. Those injected with iron were also green and were growing, but the effect was less marked than with manganese. Trials of methods of giving manganese and iron to these trees on a curative scale are now being considered, both by injection and by spraying.

Case 2. *Apples at Sutton Valence.*—The diagnosis and cure by injection methods of this severe case of iron " deficiency " have already been described. It is typical of a number of apples, pears, cherries, etc., classed as affected by " Lime induced Chlorosis ", and illustrates the characteristic balance of elements appearing in the flame spectrograms of trees, which show abnormally high calcium, strontium and (usually) magnesium and sodium, abnormally low potassium, but do *not* show low iron, which is in harmony with other workers' results. Further, spectrograms of the iron-injected, and now apparently healthy, trees show the normal balance of elements, indicating that the introduction of iron in an assimilable form enables the plant to regain a normal balance of nutrition.

Thus a spectrographer experienced in this type of work can at sight deduce a physiological shortage of iron from the general balance of line density, even when there is no absolute deficiency.

Case 3. *Grapes at Laurenceford, Cape Province.*—Analyses were made of leaves of grapes of various varieties attacked by Vlamsiekte, a bacterial disease, and corresponding healthy specimens. All healthy specimens gave spectra approximating to the " healthy balance " of fruit trees, while the unhealthy all showed some abnormality in mineral composition. This suggestion of resistance to Vlamsiekte being dependent on healthy nutrition is being followed up.

Case 4. *Mineral Deficiency in Peaches.*—Many trees, particularly peaches, on a farm at Elgin, in South Africa, have been deteriorating rapidly during the last few years. During the 1937-8 season Mr. P. E. Kriel had made detailed observations on a plantation of peaches where Peregrines were at one end and Duke of York at the other. His main finding was that both fruit and leaf buds began to die early in the season. A casual inspection gave the impression of healthy foliage but closer inspection revealed just detectable incipient chlorosis. Routine leaf injections gave slight but definite responses to nitrogen, potassium, iron and manganese. Peregrine peach leaves were selected by Mr. Kriel from the healthiest tree in a neighbouring orchard, from the healthiest trees in this orchard, from trees of medium health and from the worst trees. Quantitative spectrographic analysis gave the following results for manganese :

Healthy	·005%
,, ...	·0056%
Medium	·0017%
Bad	·0005%

The close relationship between manganese content and health is striking and is in harmony with the response to manganese injection. The response to iron injection was also in harmony with the fact that iron lines could not be detected on the plate. Subsequent large scale injections of manganese and iron did not cure the trouble, and this case is of special interest as an instance of those in which several deficiencies go together. The latest report from Mr. Kriel states that injections of boron have caused marked improvement. This element cannot be dealt with analytically at present, but we hope to do so in the near future.

Such results emphasize the point that when apparent failures of diagnosis occur, as must be expected, the diagnosis may not be wrong but incomplete—in this case manganese is undoubtedly

deficient—but other means besides flame analysis must be used to complete the chemical picture; the more complete this picture is the greater will be the certainty of diagnosis.

Analytical Methods.—*Flame Spectrographic Method used in Past.*—The above results were obtained by a modification of Ramages' flame method of spectrographic analysis, worked out by Majewsky and Roach (1939).

Ramages' method consisted in rolling 50 mg. of the dried material in filter paper and burning the roll in an oxy-coal-gas flame in front of the slit of a spectrograph. This method was improved by treating the filter paper roll containing the material for analysis with ammonium chloride vapour. This expels the more volatile organic products, thus decreasing the tendency of the roll to burst into flame, and converts the minerals into their chlorides, the high volatility of which is responsible for increasing the sensitivity of the method from thirty times for calcium to no increase for alkali metals.

Present Flame Spectrographic Method.—Recently the following further improvements have been effected.

1. The "blow-through" oxy-coal-gas jet was replaced by a standard high pressure oxy-acetylene "mixed" jet, the higher temperature resulting in a considerably increased sensitivity.
2. A manometric standardization of the flame.
3. Replacement of the Ramage manual rolling, by a mechanical folding method.

The following improvements are being perfected:

1. An automatic feed.
2. The incorporation of the sample in ammonium chloride which is compressed into a rod and fed into the flame.

Work is also in hand on the standardization of photographic methods, including a system of dealing with variations in "gamma" in individual plates.

Spark Method of Spectrography.—A new method of spark spectrographic analysis evolved by the writer is nearly ready for routine use. It consists in sparking in argon minute electrodes prepared from the plant material without addition of any foreign substance.

Polarographic Method.—Considerable improvements have been made in the polarograph and there is hope of its being put to routine use.

Chemical Methods.—A few elements remain to be determined by chemical methods. Work has been done on adapting ordinary chemical methods for our unusually exacting requirements, and this has involved some research. For example, in spite of the fact that the literature on phosphorus and silicon methods is very large and several well-known methods seemed suitable at first sight, sources of error were found in them by Mr. Eaton and Drs. Winter and Muller, and several weeks' work was necessary before the methods were satisfactory.

The present position is summarized in the Table on opposite page.

Spectrographic "Interference".—The influence of certain elements (e.g. aluminium, titanium, iron) on others (e.g. calcium, magnesium) cannot be ignored. Its degree of importance in this work is being studied and methods for dealing with it are being evolved.

Partition of Individual Elements.—If a reliable analysis shows absence or deficiency of an element that result may be regarded as conclusive, but the presence of an element in apparently adequate amount does not necessarily imply that there is no physiological deficiency. Thus in our own work leaves showing the most marked response to iron have actually contained unusually large amounts of this element—presumably in an inactive form. Similar considerations probably apply to other elements such as manganese, boron, zinc and phosphorus. Simple extraction methods capable of routine use are therefore being tried in an attempt to separate this useless form of the element from the remainder.

Certain elements enter into more than one kind of chemical combination; thus magnesium is a constituent of chlorophyll, enters into loose combination with phospholipoids and occurs in water soluble condition. Results already obtained encourage the hope that magnesium in these three states of combination can be separated by simple routine methods and estimated separately. Such figures are likely to be of greater value for diagnosis than a single figure for the total amount. Data so obtained should increase our knowledge of the functions of the individual elements and of metabolism in general.

Planning of Field Work. The results of both injection and analysis have emphasized the importance of careful selection of material. Leaves must be injected before reaching maturity if a reliable response is to be obtained. Material for analysis must be collected with a full understanding of the problem. Field work must also be organized so that full use is made of the limited period (about eight weeks) during which injection work is possible.

Conclusions.—Leaf injection and leaf analysis methods have already been used for making an extensive nutritional survey of plants and for the solution of specific mineral deficiency problems.

Deficiencies of the elements nitrogen, phosphorus, potassium, calcium, magnesium, zinc, iron,

Element	Spectrographic		Polarographic	Chemical
	Flame	Arc and Spark		
Lithium	**Good**			
Sodium	**Good**			
Potassium	**Good**			
Rubidium	**Good**			
Cæsium	**Good**			
Copper	**Good**			
Silver	**Good**			
Magnesium	**Sensitive D**			**Good**
Calcium	**Sensitive D**			
Strontium	**Sensitive D**			
Barium	**Sensitive D**			
Zinc		Probable	Probable	
Boron	Possible	Probable		
Aluminium			Possible	Probable
Titanium	Fair D	Probable D	Probable	
Carbon				**Good**
Silicon				**Good**
Tin		Probable		
Lead	**Good**			
Vanadium		Probable	Probable	
Nitrogen				**Good**
Phosphorus				**Good**
Arsenic		Probable		Good
Chromium	**Good**	Probable		
Molybdenum	**Fair**	Probable		
Sulphur			Probably good	Probably good
Manganese	**Good**	Probably good		
Fluorine			Probably good	
Chlorine				
Bromine				
Iodine				
Iron	**Good**	Probably good		**Good**
Cobalt	**Fair**	Probably good		
Nickel	**Fair**	Probably good		

In the above table heavy type indicates that the method is now in use.
D indicates that analytical difficulties are not yet overcome completely.

manganese, copper, and boron, have been determined during the routine application of injection methods. Injection methods have been worked out for application to the apple, plum, pear, peach, rose, gooseberry, blackcurrant, strawberry, potato, broad bean, lupin, raspberry, hop, tomato, tobacco, soya bean, coffee, loquat, citrus, field pea, field bean, goosblom (a cover crop), kissieblad (a malvaceous cover crop), and preliminary tests suggest that suitable modifications can also be made for monocotyledons such as cereals* and the banana. Their successful adaptation to such a wide range of plants suggests that they can be modified for use on almost any commercial crop.

Acknowledgements. The writer wishes to acknowledge Major Thompson's invaluable help for the past three years which alone made possible the development of the spectrographic side of the work. He and Dr. B. D. Bolas co-operated in writing this report.

The writer is grateful to Prof. V. H. Blackman and to Dr. R. G. Hatton for suggestions in the presentation.

* Since going to press Mr. Maynard, working in association with the writer, has perfected a method for cereals and has diagnosed deficiencies in oats.

Summary.—The mineral status of plants may be determined rapidly by either or both of two complementary methods: plant analysis and plant injection; and mineral deficiencies in large plants such as trees may be made good commercially by plant injection.

Injection.— By appropriate methods nutrient (or other e.g. antiseptic) solutions can be introduced into any part of a living plant. This part may range, as desired, from a selected area of a single leaf to the whole plant.

By localized injections and a study of the response a rapid diagnosis (two to seven days) of nutritional deficiencies may be obtained and by whole tree injections curative treatment may be carried out which gives quick results with the expenditure of small quantities of materials.

These methods have been used to study mineral deficiencies, the relation between the nutrient salts present in the soil and those actually present in the leaves, and in the treatment of certain diseases either with nutrient salts or with antiseptics. Good results have been obtained in the treatment of Silver Leaf and Red Spider.

In an extensive series of experiments carried out in South Africa the value of the methods both for diagnosis and treatment was confirmed, and results of great commercial value were obtained. Peach trees, for example, which produced no crop before injection produced a crop worth £2 to £5 per tree after an injection costing 2d. per tree.

Leaf Analysis.—Spectrographic and chemical methods of leaf analysis have been evolved which are extremely rapid and sufficiently accurate for a number of elements—spectrographic, for lithium, sodium, potassium, rubidium, cæsium, copper, silver, lead, chromium, manganese, iron, magnesium, calcium, strontium, barium, molybdenum, cobalt and nickel, and chemical for phosphorus, nitrogen and silicon. Special methods of analysis for the separation of individual elements into the portions which fulfil different functions in metabolism are being developed.

It has been possible to study mineral deficiencies, the relation existing between soil and plant and to make good mineral deficiencies by injection.

References

Atkinson, J. D. (1935). "Progress report on the investigation of corky-pit of apples." *N.Z.J. Sci. Tech.*, **16**, 315-19.

Dunne, T. C. (1938). "'Wither tip' or 'Summer dieback'. A copper deficiency disease of apple trees." *J. Dep. Agric. W. Aust.*, **15** (2nd ser.), 120-26.

Jamalainen, E. A. (1936). "Boorin vaiktus kuoppataudin esiintymiseen omenissa. (The effect of boron on the cork disease in apples.)" [Finnish, English Summary, 4 pp.] *Valt. Maatalousk. Julk.*, **89**, pp. 19.

McLarty, H. R. (1936). "Tree injections with boron and other materials as a control for drought spot and corky core of apple." *Sci. Agric.*, **16**, 625-33.

Majewsky, F. and Roach, W. A. (1939). "Flame Method of Spectrochemical Analysis." *Nature*, **144**, 1047.

Moore, M. H. (1940). Personal communication.

Roach, W. A. (1934). "Injection for the diagnosis and cure of physiological diseases of fruit trees." *Ann. appl. Biol.*, **21**, 319-43.

Roach, W. A. (1935). "Tree injection—Invigoration by the injection of fertilizers." *Rep. E. Malling Res. Sta. for 1934*, pp. 135-8.

Roach, W. A. (1938). "Plant injection for diagnostic and curative purposes." *Tech. Comm.* **10**, *Imp. Bur. Horticulture and Plantation Crops.*

Teakle, L. J. H. (1937). Letter to writer dated 6.8.37.

Young, L. C. and Bailey, C. F. (1936). "Progress report on the investigation of corky core of apples." *Sci. Agric.*, **17**, 115-27.

MYCOLOGY AND BACTERIOLOGY

NOTES ON PLANT DISEASES IN 1939

By H. WORMALD and R. V. HARRIS

Non-Parasitic Diseases of Fruit Trees.—Of those diseases not caused by parasites some were attributed to the somewhat unusual weather conditions at certain periods of the year. Thus the wet winter and spring caused some soils to become waterlogged, a condition detrimental to the roots, and, as a result, we received a number of enquiries as to the cause of death of young apple trees. It was ascertained that most of these trees had been growing in heavy soil very liable to waterlogging.

On one farm the grower lost about thirty 3-year-old apple trees, mostly Ellison's Orange, but also a few Cox's Orange Pippin on rootstock No. II, and specimens of Cox's Orange Pippin on rootstock No. II received from Essex showed the same type of damage. Injury of this kind is known as "The Death". Orchards subject to waterlogging should be well-drained, and young trees should be securely staked to prevent too much movement of the stem during high winds. With insecure staking a space may appear in the soil round the stem; water collects in this space and if this condition persists too long the bark on the lower part of the stem, and on the larger roots, will decay, and the death of the tree results.

An instance of "The Death" in Norfolk Giant raspberries was noticed at Wateringbury, Kent; the plantation was on soil with an impervious layer at a little distance below the surface, a type of soil quite unsuitable for raspberries. Other raspberry plants with dead roots, probably killed by similar conditions, were received from Brenchley.

Papery Bark.—The condition known as Papery Bark was seen on specimens of Williams' pear and Benn's Red apple trees from Suffolk, and on pear shoots from Faversham, Kent. In this disorder the bark becomes unevenly swollen and blistered; the blisters burst and the bark peels off in a thin papery layer. The cause of this is not yet fully understood, but it is probably brought about by a sudden upward flow of sap; this might happen during a wet period that succeeds a period of drought, and it might also be caused by hard pruning or cutting back at a time when the roots are very active.

"Cox Spot."—A spotting of apple leaves known as "Cox Spot" because of its prevalence on Cox's Orange Pippin was very severe in some plantations. The discoloured spots are almost circular; no parasitic organism has been found on them and the spotting is considered to be brought about by drought conditions such as those which prevailed in the early summer of 1939.

"Czar Spot."—A spotting of Czar plum leaves is probably also due to drought. These spots bear a superficial resemblance to those caused by bacterial infection, but they are usually rather larger, and there is a very definite pale ring or "halo" round each. Again no organism has been found in such spots and the prevalence of the disorder during the early summer of 1939 suggests that the dry weather at that period was the cause.

Dwarf Lateral Scorch of Raspberries and Die-back of Loganberries.—Recent experiments have shown that the range of symptoms described in previous issues of this Annual Report under the above and other names* are primarily the result of an imperfect breaking of the winter "rest period" owing to inadequate exposure to low temperatures in the winter months.† They are therefore directly caused by mild winters. With the exception of a brief continuously cold period in December the winter of 1938-9 can be described as generally mild, mean temperatures for January and February being 41° and 42° F. respectively. As was anticipated therefore we received numerous enquiries about this disorder during 1939, notably in Lloyd George raspberry and in loganberry.

"False Crinkle" of Strawberries.—From early June our attention was frequently drawn to certain symptoms prevalent on the leaves of Royal Sovereign plants, namely, a reddish coloration distributed marginally or more frequently as scattered spots. The latter somewhat resembled the lesions of the crinkle (virus) disease on overwintered leaves, and in several instances the disorder was diagnosed as severe-crinkle. Further investigations in the field, however, showed that the symptoms were generally limited to maiden-plantations planted late in the previous autumn and, on lifting, the roots of affected plants were always found to be heavily caked with lumps of soil and very deficient in new root-fibre, which, in the earlier examinations, was entirely lacking on many of the plants.

It was therefore thought that the symptoms might be primarily the result of nutritional deficiencies promoted by a delay in the spring production of new root fibre. In support of this it was found that the trouble always occurred on heavy types of soil in a "poorly working" condition owing to (1) deficient cultivation and manuring and (2) the generally mild and wet winter followed by an exceptionally early drought in May and June.

The affected plantations rapidly responded to the break-up of the dry weather in mid-June by the belated production of root-fibre, and this was followed by the production of new leaves which, except for the usual sparse mild-crinkle lesions, were entirely normal in appearance.

As a final confirmation, plants showing typically severe symptoms were transferred from several affected plantations to a standard greenhouse compost in pots, and were placed in a cold frame. All those plants surviving transplantation subsequently made complete recovery, growing into plants normal in every respect except for the usual mild-crinkle lesions. As a further test plants in this series were stolon-grafted to Royal Sovereign plants entirely free from crinkle and yellow-edge, and without exception mild-crinkle only was transmitted.

It was therefore concluded that the symptoms in question were distinct in origin from those of

* *E. Malling Res. Sta. Ann. Rep. for 1936* (1937), p. 187.

† *Report for 1937* (1938), p. 93, and the present *Report*, p. 29.

severe-crinkle and were primarily due to a combination of local soil and weather conditions unfavourable to the normal development of new root fibre.

Fungous Diseases of Fruit Trees.—*Coral Spot Canker.*—Reference to Coral Spot Canker on apple trees has been made in previous reports. These cankers are sometimes of great length and may cause much damage. A branch of a 4-year-old Ellison's Orange apple tree received from Witham, Essex, was girdled by a canker 20 inches long, bearing throughout its whole length pustules of the conidial stage of *Nectria cinnabarina*. The grower wrote : " The disease has attacked the tree near the head and is spreading rapidly to the branches around the point where they leave the main stem." Later another tree of Ellison's Orange on the same farm was seen to be attacked. Growers are reminded that Coral Spot occurs frequently on currant bushes, particularly the red currant, so any currants in the vicinity of apple trees should be examined and any diseased branches removed and burnt immediately.

Silver Leaf.—The Silver Leaf fungus, *Stereum purpureum*, attacks a large number of woody plants and is sometimes found in unexpected places or on unusual hosts. In 1939 we saw the fungus producing fructifications freely on the posts used to mark out the plots in an allotment garden. There were no fruit trees in the allotments themselves, but there was a fruit plantation not very far away.

On this Station fructifications of the fungus were found in November on a walnut tree which had been cut back in order to induce the production of shoots for budding. The fungus had entered through the cut end of a branch and was killing back the branch.

Fruit Rot following Apple Scab.—Apples, variety Cox's Orange Pippin, received towards the end of December showed circular, sunken (saucer-shaped) areas one-fifth to one inch in diameter. On some of these blotches there was the Bitter Rot fungus, *Gloeosporium album*, on others the Pink Rot fungus, *Trichothecium roseum*. In the centre of each blotch there was a scab lesion, so that it was evident that the rot-producing fungi had entered through the injuries caused by the scab fungus. To guard against such wastage in the store, therefore, attention must be given to the control of scab by the usual routine methods. If seriously scabbed fruit is stored there is a risk of serious loss from rot fungi infecting through the scab lesions.

Brown Rot Diseases.—Blossom Wilt, caused by *Sclerotinia laxa* (*Monilla cinerea*) was not very prevalent, but in certain orchards, where the disease had been neglected, severe damage was experienced on apple, sweet cherry, and Morello cherry trees. It was seen also in gardens on the apricot and on two ornamental plants, *Prunus tomentosa* and *Pyrus japonica*.

A very destructive outbreak of Blossom Wilt occurred in an 8-acre plantation of Morellos at Goudhurst, Kent. The trees had come normally into blossom and gave promise of a good crop. By the middle of June, however, the plantation appeared to have been swept by fire, and the effect of the dead, brown foliage and withered flowers could be seen at a distance. On some trees all the blossom was destroyed, and many others bore only a few scattered fruits. Even on the trees least affected about half the blossom was destroyed. Dead twigs bearing the fungus (a result of infection in 1938) were present on the trees and it was evident that many twigs had been killed in 1938—not enough, however, to alarm the grower so no steps had been taken to cut out the dead twigs that year. The result was, that as weather conditions at blossoming time in 1939 were particularly favourable for infection, there was an outbreak on a large scale. Most or all of the infection occurred through the open flowers since no infection of unopened flowers was observed. It was estimated that the loss due to Blossom Wilt in this plantation was at least £1,000, for not only was the expected crop reduced to less than half, but the labour charges involved in cutting out all the dead twigs and branches must have been considerable. Moreover, the fruiting surface for the 1940 crop was much reduced owing to the death of numerous branches and the cutting back necessary to remove the sources of future infection. Such a loss could have been avoided if the relatively slight infection of 1938 had been noticed and the necessary steps taken to have all the dead twigs removed that year. Such measures, and the danger which may be incurred by neglecting them, have been frequently mentioned in the Reports of this Station and in other publications.

Brown Rot of the fruit was checked by the dry conditions of early summer, but later, with the advent of wet weather, infection of apples, pears, and plums occurred. More than seventy infected fruit were counted on one tree of Shepherd's Bullace on this Station, some of them in clusters of four to twelve, when the infection had started in one fruit of a cluster and then spread to the rest. This infection was caused almost solely by *Sclerotinia fructigena* (*Monilia fructigena*) ; only four fruits bearing *Monilia cinerea* were seen on the tree. Two other trees of Shepherd's Bullace had fewer infected fruit, only about twenty in all, and all bore *Monilia fructigena*.

Angular Leaf Spot.—This disease of apple leaves, mentioned in the Report for 1938 (p. 168) was observed in other localities in 1939. As the name indicates, the spots are definitely angular, and not almost circular as are most leaf spots. A description of this disease appears later in this Report (p. 63).

Sooty Blotch.—Owing to the dry weather in early summer there was comparatively little Sooty Blotch (*Gloeodes pomigena*) in 1939. It was not seen on apples on this Station, but specimens showing rather severe blotching were received from Trottiscliffe, Kent, and from Berkshire and Hampshire. On plums, too, there was less than usual and it was not found on the chief varieties on the Station, including Warwickshire Drooper which often shows severe infection. About the middle of October, however, a few fruits with Sooty Blotch were found on a tree of Shepherd's Bullace, but the attack was very slight.

Medlar Leaf Blight.—A severe outbreak of Leaf Blight caused by *Fabraea maculata* (*Entomosporium maculatum*) again occurred on the tree at West Malling, where the disease was observed in 1938. In 1939 not only were the leaves infected, but lesions with Entomosporium fructifications were found on the young shoots and on the fruits.*

Currant Leaf Spot.—The Gloesporium leaf spot disease of black currants was less troublesome than usual; this again was due to the dry weather in early summer. On this Station there was comparatively little infection and the bushes retained their leaves until well into November. In a plantation at Goudhurst, however, there was a severe outbreak on Boskoop Giant, resulting in premature leaf-fall early in June.

Grey Mould on Currant Leaves.—Early in September many leaves on a plot of Wellington's XXX black currants were seen to be infected with Grey Mould, *Botrytis cinerea*, the symptoms being large discoloured blotches. Most of the blotches occurred towards the margins of the leaves, many of them affecting the terminal lobe, suggesting that infection had started at the apical tooth; water would tend to accumulate at the apex of drooping leaves and such conditions would favour infection by Botrytis. Usually there was only one blotch on a leaf, but sometimes there were two, and often more than half the leaf was affected. The infected areas were brown, usually dark brown towards the edge in the larger blotches. Close narrow ridges were seen on the upper surface of some of them. Outside the actual dead area there was a broad yellowish zone that gradually merged into the normal green of the healthy parts of the leaf. On the underside of the blotches there were scattered fructifications of *Botrytis cinerea*. As this disease did not appear until late in the season it caused little damage and no control measures were taken, but in a really wet year it might be troublesome.

Raspberry Cane Blight.—An exceptionally heavy infection by the Raspberry Cane Blight fungus *Leptosphaeria Coniothyrium* in 1938 resulted in a widespread dying of fruiting canes during 1939 on the Research Station variety trial plots, Newburgh, Preussen, Viking and Red Cross being the varieties chiefly affected. Newburgh, a variety of American origin, has up to the present proved exceptionally free from disease and of promising performance under East Malling conditions. The attack on this variety was particularly severe, all the fruiting canes being killed on some of the stools.

In late July numerous incipient lesions were noted on many of the first-year canes of a plantation of *Norfolk Giant* in a neighbouring farm. In this outbreak the severity of attack was associated with local conditions of high humidity resulting from vigorous cane growth (many canes reaching 8 feet in height) combined with a very close plant of 6 feet between the rows.

Bacterial Diseases of Fruit Trees.—Bacterial Canker of plum and cherry trees was generally less severe than in previous years, but in a plantation of 6-year-old President plum trees at Borough Green about 5 per cent. were affected. On this Station two Cherry Plum (Myrobolan) trees were killed by Bacterial Canker. As in other varieties of plums, stem cankers in the Cherry Plum are associated with leaf infection. Twigs from trees of this variety received from Paddock Wood showed very severe leaf spot.

Early in May there was much leaf infection on certain varieties of cherry on this Station. On Cryall's Seedling some leaves had very numerous small angular bacterial spots. The disease was severe on Wellington also. Later this leaf infection was found associated with blossom blight particularly on the variety Early Rivers. A similar blossom blight accompanied by severe leaf spotting was seen at Egerton, again on Early Rivers. After the fruit had set bacterial lesions were found on the fruit and fruit stalks of Early Rivers and other varieties on the Station.† The organism associated with this blossom blight of sweet cherries was isolated and preliminary cultural tests indicate that it is probably identical with *Pseudomonas mors-prunorum*, the cause of Bacterial Canker in plum and cherry trees.

There was also severe leaf and blossom infection on Morello cherries. Blossom Blight and Leaf Spot has been observed in previous years on Morellos, but in 1939 infection of the flower trusses was more general than ever before; on some trees more than half the blossom was killed. Later, bacterial lesions were present on the fruit stalks. Two organisms were found associated with such infection on Morellos; sometimes one was isolated, sometimes the other. One of these organisms is closely

* Observations made by M. H. Moore.

† Observations by H. B. S. Montgomery.

related to *P. mors-prunorum* if not identical with it. The other shows cultural characters which distinguish it from both *P. mors-prunorum* and *P. prunicola* ; it has not yet been identified. On one plot of Morello several trees were killed by bacterial cankers at the base of the stems.

Blossom blight of pears was again severe on certain varieties on the Station, particularly Catillac, Emile d'Heyst, Durondeau, Pitmaston Duchess, and Beurré d'Amanlis. The organism usually isolated from the dead spurs is referred to as *P. prunicola*, but inoculations of pear flowers with this organism have hitherto given negative results.

Diseases of Hops.—*Crown Rot.*—A crown rot of hop plants attributed to *Armillaria mellea*, the Honey Fungus, was found on eight farms in Kent during 1939.* Although, in the absence of rhizomorphs and fructifications, there is no conclusive proof that the Honey Fungus is responsible it seems highly probable to be the cause. The symptoms are a rotting of the crown, and when the bark is stripped off a white layer of mycelium is seen between the bark and the wood. These symptoms are similar to those described by Salmon and Ware† who found rhizomorphs of *Armillaria mellea* associated with the disease. Although crown rot is not so serious as certain other diseases of the hop it does at times result in the death of hills. In one outbreak, at East Peckham, twenty hills were affected in a patch where a hedge had been grubbed, and there was a similar affected area at Headcorn, also on the site of an old hedge. On a farm at Mereworth several hundreds of hills were affected in a 4-year-old garden on the site of an old apple and nut plantation.

Hop Canker.—Canker or " Growing Off " was seen in a hop yard in Worcestershire and at West Farleigh and Faversham, Kent.‡ This disease is caused by *Gibberella pulicaris* (*Fusarium sambucina*),§ and both stages of the fungus were found on some of the affected bines. Where this disease is prevalent attention should be given to drainage as it is generally most severe following waterlogging in winter.

Verticillium Wilt.—This disease continues to extend its range and in 1939 it was found on twenty-seven farms where it had not previously been reported ; two of these were in Herefordshire, and one in Hampshire, while the rest were in Kent. When it appears in a hop garden drastic measures to eradicate it should be adopted or there is the risk that the garden will become unprofitable within a few years.

An account of the investigation of this disease in 1939, by W. G. Keyworth, appears in the *N.F.U. Journal* for December, 1939.

Downy Mildew.—Downy Mildew was not very troublesome during 1939, partly owing to the dry weather in early summer, and also because routine spraying against it with Bordeaux mixture is now widely practised. One severe outbreak, however, was noticed at Goudhurst, but here the hops were interplanted with mangolds, and, as a result, the hops could not be sprayed, and the cones became so badly infected that they were not worth picking.

Grey Mould.—Grey Mould, *Botrytis cinerea*, sometimes attacks hop cones. Infection may occur at the tip, which turns brown ; at other times some of the " petals " become infected separately and these brown petals give the hop cone a flecked appearance. Early in September a number of cones on two Mexican seedling hop plants at the Station showed these flecks, one to six petals on each cone being brown and bearing Botrytis fructifications. A few days later hops brought in from a farm at Maidstone showed the same disease.

Nettlehead.—Nettlehead, suspected of being a virus disease, is known to occur in many hop gardens, and a survey made in 1939 shows that it is widespread and very destructive. An intensive study of this disease is being made to obtain more exact information as to its cause and mode of spread. The work is being carried out by Mr. W. G. Keyworth and Dr. D. L. G. Davies under a fund subscribed by hop-growers (see the *N.F.U. Journal* for February, 1940, p. 56).

Summary.—Notes are given on features of interest in diseases of fruit trees and hops observed during 1939.

* Observations by W. G. Keyworth and D. L. G. Davies.
† *Journ. of S.-E. Agric. Coll.*, **40**, *1937*, 18-26.
‡ Observations by D. L. G. Davies.
§ Davies, D. L. G., *Ann. Rep. Long Ashton Res. Sta. for 1938*, pp. 115-23.

THE ANGULAR LEAF SPOT OF APPLE TREES

By H. WORMALD

A DISEASE of apple leaves, noticed in this country for the first time in 1937 but seen on the Continent two years previously, seems to be extending its range, for in 1939 it was found in six localities, in four counties. At present it is not causing any appreciable damage, but growers are asked to be on the watch for it in order that information may be obtained as to whether it is really becoming more prevalent and whether it is likely to become a serious trouble in apple orchards.

This disease appears to have been first observed in Austria, in August, 1935, when it was found in three nurseries. The characteristic symptoms of the disease were numerous small, angular, yellowish or greyish spots, which were very conspicuous on the upper surface but less noticeable below. Spots frequently occur on apple leaves but they are usually more or less circular, or somewhat irregular in shape, so that the very definite angular form of the spots of the new disease served as a distinguishing feature.

Wenzl (1936), who first described the disease, found on some of the spots a fungus, a species of Phyllosticta, which, from its association with the characteristic spotting, he named *Phyllosticta angulata*. This fungus was assumed to be the cause of the spotting, but no experimental evidence in support of this conclusion was given.

A similar angular spotting of apple leaves was observed in July, 1937, in a well-cultivated orchard of Bramley's Seedling and Worcester Pearmain trees at Lingfield, Surrey, but apparently it was causing no real harm. This first appearance of the disease in Britain was recorded by Salmon and Ware (1938). In August of the same year (1937) Mr. R. G. W. Bush found the disease " in a badly neglected orchard near East Grinsted, Surrey, on leaves of Worcester Pearmain, Bramley's Seedling, Allington Pippin and Newton Wonder, but here again it was causing little or no damage ". These two outbreaks were described by W. C. Moore (1939), who referred to the disease as " Angular Leaf Spot of Apple ". He also found a Phyllosticta on some of the spots and although this fungus did not quite conform to the original description the discrepancies were so slight that it was considered to be the same species as that found by Wenzl. Moreover, Moore was able to obtain leaves showing the disease from Dr. Wenzl and from a comparison of Wenzl's fungus with that found by himself he concluded that both belonged to the same species.

On some of the spots Moore found also a fungus which " produced compact tufts of dark conidiophores ", but this fungus was not identified.

In 1938 the disease appeared again at Lingfield and about the middle of July Mr. Bush kindly sent me apple leaves showing this leaf-spot. The spots were definitely angular, and when examined with a lens they were seen to be bounded by the smaller veins so that each spot had four or more straight sides (Fig. 1*b*). They were yellowish-green and on some of the leaves they were very numerous, sometimes two to three hundred on one leaf. The individual spots were very small (mostly about 1/25 inch in diameter) but where they were numerous they were sometimes in streaks, and often confluent to form larger, more irregular, but still angular, spots or blotches. The spots were examined carefully but no fungal fructifications were found on them.

In 1939 the same disease was observed in other localities. Mr. Bush informed me that he had seen it at Kirdford and at Fittleworth (Sussex), Alton (Hampshire), Danbury (Essex), and Paddock Wood (Kent), while Mr. M. H. Moore of this Station saw the characteristic spotting in a single leaf in an orchard at Brenchley, Kent.

The most severe outbreak was the one at Kirdford and I am indebted to Mr. W. Fowle for the following information about its occurrence there :

" I have noticed Angular Leaf Spot for the last few years here but have never attached much importance to it though it seems to be showing up much more this year than in previous seasons. Even now I do not think it has reached economic proportions. In a few cases one can find nearly all the leaves on a spur rather severely affected but seldom more than a few spurs on each tree showing any damage.

" Worcester Pearmain, Bramley's Seedling, King of the Pippins and Blenheim Orange seem to be most severely affected here. It occurs on all the trees in one field more severely than in other plantations; in this field the trees are in grass and about nine years old, and apart from this damage are carrying a very good leaf.

" The disease can be found in cultivated plantations as well as among the trees in grass, but it is very much more common on the grass field. In the plantations it is difficult to find a single leaf severely affected and more generally a few spots only are on each leaf, and the affected leaves are few and far between."

About the middle of September Mr. Fowle sent me leaves from affected trees. The spots on these leaves were mostly silvery-grey but those of the younger leaves were yellowish and similar to those seen in July the previous year. The grey spots on the older leaves evidently represented a later stage of the disease than the yellow spots, and on such grey shoots there were fructifications of two species of fungi, usually separately, but occasionally both were found together on the same spot. One of these fungi was a Phyllosticta (seen as black dots with a lens). The other consisted of tufts of brown hyphae, mostly barren, though a few spores were seen associated with them ; this is probably the form producing "compact tufts of dark conidiophores" seen by W. C. Moore. The colour and form of the conidiophores suggested that the fungus was a Cladosporium. Mr. E. W. Mason, of the Imperial Mycological Institute, kindly examined leaves bearing this fungus and confirmed that it was a Cladosporium, probably *C. herbarum*. On leaves received later (towards the end of October) a species of Alternaria also was found, but again most of the spots bore one or other of the two fungi above mentioned, a Phyllosticta and a Cladosporium.

The Phyllosticta found on the leaves from Kirdford did not conform to Wenzl's description ; the fructifications (pycnidia) were larger and had larger pores, and the spores, though only slightly larger on the whole than those of *P. angulata*, had mostly two distinct " oil-drops " (or guttulae) one near each end of the spore. Wenzl stressed the point that in *P. angulata* the spores do not contain oil-drops. The size of the spores and the presence of the oil-drops conform to a fungus described and figured by Salmon (1908), but this fungus was found on rather large, almost circular spots.*

The Phyllosticta of the Kirdford material was isolated and grown in pure culture for further study.

Mr. W. C. Moore, who had isolated *Phyllosticta angulata* from the leaves sent to him by Dr. Wenzl, kindly sent me a culture of this fungus. In parallel cultures, on the same medium, the two fungi (that from Wenzl's material and the one isolated from the leaves received from Kirdford) behaved differently, in their rate of growth and in general habit. The two fungi are therefore not identical though they may be merely divergent forms within one species.

The relation of these various fungi, found on affected leaves, to the spotting—particularly whether one or other is the primary cause of the spots—can be determined only by inoculation experiments.

There is no evidence at present that this disease produces premature leaf-fall or that the reduction of the effective leaf surface by the spotting, even when this is severe, tends to weaken the trees, but further observations on these points are necessary before final conclusions can be drawn. Meanwhile growers who find this Angular Leaf Spot in their orchards are asked to send particulars of the outbreaks to this Station so that information can be collected as to its distribution, the extent of the damage caused by the disease, and the conditions under which it appears.

I am greatly indebted to Mr. R. G. W. Bush and Mr. W. Fowle for sending me apple leaves showing the disease, to Mr. W. C. Moore for information concerning the Phyllosticta he examined, and for supplying a culture of the fungus isolated from a leaf sent to him by Dr. Wenzl, and to Mr. E. W. Mason for examining the Cladosporium on affected leaves.

Summary.—Angular Leaf Spot of apple trees, first seen in Britain in 1937, was found during 1939 in six localities, in four counties. The fungi that have been found on the spots are briefly described.

References

Grove, W. B. (1935). " British Stem and Leaf-Fungi. Vol. I, Cambridge," p. 41.

Moore, W. C. (1939). " Angular Leaf Spot of Apple (*Phyllosticta angulata* Wenzl)." *Trans. Brit. mycol. Soc.*, **22**, 264-6.

Salmon, E. S. (1908). "'Leaf-Spot' Diseases of the Apple." *Journ. of S.-E. Agric. Coll.*, **17**, 316-19.

Salmon, E. S. and Ware, W. M. (1938). *Journ. of S.-E. Agric. Coll.*, **41**, 16.

Wenzl, H. (1936). " Eine neue Blattfleckenkrankheit des Apfels (*Phyllosticta angulata* n.sp.)." *Phytopath. Z.*, **9**, 349-56.

Wormald, H. (1939). " Angular Leaf Spot." *Rep. E. Malling Res. Sta. for* 1938, **A22**, 168.

APPENDIX

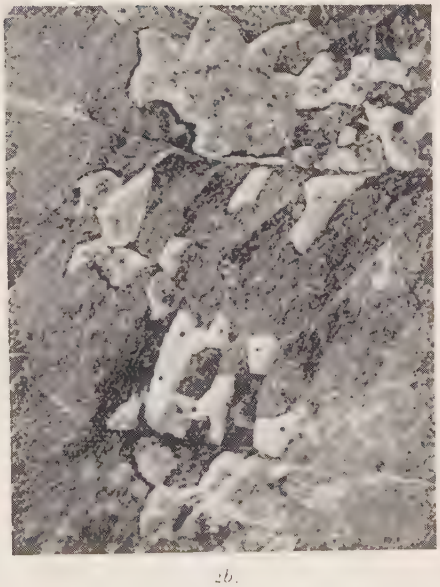
While the above article was in the press Dr. Massee and Mr. Steer found an angular leaf spot on apple and pear trees at Tenterden, Kent (27th May, 1940), associated with severe infestation by a frog-hopper *Cercopis sanguinea* Geoff. (=*Triecphora vulnerata* Illig.). In size, shape, and irregular distribution (sometimes in streaks) over the leaf, the spots resembled those described above, but they were dark brown or reddish-brown, frequently much darker than the normal green of the healthy parts of the leaf, and not yellowish or silvery grey.

* The fungus described by Professor Salmon is included by Grove (1935) under *Phyllosticta Mali*.

1*a*.

2*a*.

1*b*.



2*b*.

FIG. 1.

Angular Leaf Spot of Apple.

1*a*. The disease as seen at an early stage (July).
1*b*. Portion of a leaf at the early stage as seen with a lens (×4).
2*a*. The disease at a later stage (September).
2*b*. The spots now (September) bear fungus fructifications. The black dots are pycnidia of a *Phyllosticta*; the large spot near the top bears a *Cladosporium*.

Shortly afterwards (early June) Mr. Fowle sent us apple leaves, showing dark brown angular spots, from the same orchard where Angular Leaf Spot had been found in 1939; we were informed that " the large red and black frog-hopper is abundant ".

Trees with these early manifestations of angular leaf spot (dark brown spots) are under observation to determine whether or not the two types of spotting are phases of one and the same disorder. Dr. Massee and Mr. Steer have already proved by experiment that the frog-hopper is the primary cause of the dark brown angular spots, and damaged leaves will be kept under observation to determine what fungi (if any) develop on such spots.

REVIEW OF RESEARCH ON STRAWBERRY VIRUS DISEASES, 1932—1939

By R. V. HARRIS and M. E. KING

I.—Yellow-edge.

In 1932 this disease was identified on the variety Royal Sovereign by means of stolon-grafting transmissions (Harris, 1933), and in 1934 Massee transmitted the disease to the same variety by the agency of the common strawberry aphis *Capitophorus fragariae* (Massee, 1935).

Subsequent research has been concerned mainly with the development of a system of commercial control for that variety based on the maintenance of supplies of disease-free runners by the systematic roguing of specially designed propagating nurseries, and on the control of the insect vector (Rogers *et al.*, 1939).

The efficiency of the former method depends primarily on the degree to which infected plants exhibit diagnostic symptoms.

Symptom Expression in Royal Sovereign.—(*a*) *Seasonal Fluctuation.*—A tendency for the masking of symptoms was early observed in this variety and in 1935 a field experiment was started to study the relation of this phenomenon to the plant environment. Clonal series of plants were simultaneously infected in the field by stolon grafting each plant to an " infector " from a clonal series of yellow-edge plants of the same variety. The symptom-intensity on a standard numerical scale was then recorded for individual plants of each series at weekly or fortnightly intervals throughout each subsequent season up to and including that of 1939. From these data fluctuations in symptom-expression were examined in relation to air and soil temperatures, rainfall, etc. Latterly a Rogers' Soil Tensiometer was installed on the plot and in 1939 striking correlations with soil moisture were obtained. From such correlations it is now possible to predict with considerable accuracy the optimum time in a particular season for the inspection and roguing of Royal Sovereign runner-beds.

(*b*) *Individual Plant Variation.*—In spite of the precautions taken to ensure a general uniformity of infection within each group of plants in the above experiment, the records indicate a considerable plant to plant variation in disease intensity, extending also to the runner progeny. Thus although most of the plants were affected uniformly mildly, some developed and maintained conspicuously severe symptoms from the time of infection.

From 1936 to 1938 experiments in the open ground and in pots were made in order to determine the possible influence of soil nutrition on such contemporary variations in symptom intensity. These yielded negative results, thus confirming that the severe and mild expressions of symptoms are determined primarily by virological rather than plant environmental factors.

In 1939, working on the hypothesis of multiple virus strains, Royal Sovereign plants infected with Yellow-edge of known and varied intensities were exposed to a range of temperatures in warm water baths for periods of differing length, in order to examine a possible lethal action of high temperature on their virus content. The results of this experiment are not yet available.

Relative Varietal Susceptibility and Symptom Expression.—In 1933 and 1934 one of the present writers (R.V.H.) working in Eastern Canada,* compared Yellow-edge on Royal Sovereign with the analogous Yellows or Xanthosis of North America by means of stolon-grafting tests, using Royal Sovereign as indicator. From these experiments he and his Canadian collaborator, Dr. A. A. Hildebrand, showed that certain of the local American strawberry varieties commonly reacted as symptomless-carriers of the disease (Harris and Hildebrand, 1937).

In 1935 at East Malling the study of Yellow-edge in Royal Sovereign was resumed and extended to include species of Fragaria and other commercial varieties. Wide differences in degree of

* Under an exchange of workers arrangement by the Ministry of Agriculture and Fisheries.

susceptibility and symptom-expression were shown by the early transmission experiments. Thus *Fragaria chiloensis* reacted as a symptomless-carrier of the disease with high resistance to deterioration, and at the other end of the scale *F. virginiana* (cultivated in this country as " Little Scarlet ") and the native woodland species, *F. vesca*, were found to combine a high degree of symptom expression with extreme susceptibility to deterioration. Preliminary trials have further indicated that the existing commercial varieties form a series between the extremes represented by their parent species (*F. chiloensis* and *F. virginiana*) some varieties, e.g. Lefebvre and Huxley's Giant approximating in reaction to the former, and others, e.g. Royal Sovereign and Sir Joseph Paxton, to the latter species.

It follows from these results that the maintenance of supplies of virus-free runners by the roguing of infected plants presents greater practical difficulties in those varieties approximating more closely in reaction to the " symptomless-carrier " type. Varieties of this group, moreover, provide a potent source of infection for those of the " susceptible " group and many specific instances of severe injury to Royal Sovereign plantations by interplanting with varieties of the "symptomless-carrier" group have been recorded in recent years.

On the other hand in concentrated strawberry growing areas where adequate isolation of " susceptible " varieties from sources of infection is impossible, there is naturally a demand for vigorous stocks of the symptomless-carrier type of variety.

The need for a final determination by experiment of the reaction of each individual variety to Yellow-edge as an essential preliminary to the formulation of appropriate control measures, thus became increasingly apparent. Having achieved in some measure this object with Royal Sovereign, research at the present time is being similarly directed to a selected range of other named and seedling varieties* including representatives both of the provisional susceptible and symptomless-carrier groups (see p. 29).

As a necessary preliminary to these experiments the collection and testing of samples in order to discover as far as possible sources of " virus-free " plants of each selected variety was started in 1937. *Fragaria vesca* has hitherto served as the indicator in these tests but, although extremely efficient for the detection of the Crinkle disease (*q.v.*), it has not proved to be an ideal indicator for Yellow-edge, and in 1939 samples of *F. indica* and *F. virginiana* (from N. American sources) were raised from seed in order to test their efficiency in this respect.

II.—Crinkle.†

Mild Crinkle in Royal Sovereign.—The identification in 1935 of an extremely mild form of this disease in apparently normal Royal Sovereign plants considerably complicated the virus problem in this variety. In that year and in 1936 *Fragaria vesca* plants stolon-grafted to Royal Sovereign were found to react as extremely sensitive indicators of this disease and by its use the principal Yellow-edge rogued clone of Royal Sovereign under propagation at the Research Station, although confirmed to be free from Yellow-edge, was found to be totally infected with Mild Crinkle.

Mild Crinkle, in addition to Yellow-edge, was also invariably registered by *F. vesca* when grafted to Yellow-edge infected Royal Sovereign plants.

An explanation of the wide distribution of Mild Crinkle and of its constant association with Yellow-edge was provided in 1938 when Massee showed that *Capitophorus fragariae* is a common vector of both diseases.‡

In 1938 numerous samples of Royal Sovereign were procured from a local stock in western Ireland (County Mayo) introduced in 1905 (shortly after the introduction of the variety to commerce) and subsequently cultivated in almost unbroken isolation from other varieties.

Most of these samples, on grafting to *Fragaria vesca*, proved to be entirely free from both Yellow-edge and Crinkle, and thus provided material for etiological studies of the diseases and for the assessment of the commercial importance of Mild Crinkle.

In 1939, therefore, a small-scale pomological trial was laid down for comparing the performance of the Mild Crinkle infected clones of Royal Sovereign with clones raised from selected plants of the Irish strain.

The Etiology of Mild and Severe Crinkle.—The symptoms of Severe Crinkle are qualitatively identical with those of Mild Crinkle but are of greatly increased intensity. In 1939, in collaboration with the Entomology Section comparative transmissions by the agency of both aphis and grafting were made, from mild and severe crinkle plants respectively, to crinkle-free Royal Sovereign and *Fragaria vesca* plants. The results varied both according to the mode and the source of infection, and showed conclusively the etiologically distinct but closely related nature of the diseases. Thus with grafting transmission severe-crinkle plants invariably induced severe-crinkle symptoms and

* In collaboration with the plant breeder.

† See also *E. Malling Res. Sta. Ann. Rep. for 1937*, p. 201.

‡ *E. Malling Res. Sta. Ann. Rep. for 1938*, p. 96.

mild-crinkle induced mild-crinkle, but with aphis transmissions a minority of the infections derived from a severe or a mild affected source developed symptoms of converse intensity, i.e. severe plants were derived from mild sources and vice versa. The etiological and practical implications of these results—that mild affected plants may be potential sources of the severe disease—will be investigated by further experiments aimed at the elucidation and control of the factors determining the passage of plants from the mild to the severe condition.

III.—Mechanical Transmission and Differential Hosts.

Numerous attempts to transmit Yellow-edge and Crinkle by mechanical methods to species of *Fragaria* and to the cultivated strawberry have so far failed. Many attempts have also been made to infect plants of other genera and families both by mechanical means and by grafting. The former method of infection yielded positive results in one instance, necrotic lesions of a very localized nature being induced on leaves of tobacco (*Nicotiana tabacum*) by inoculations from Crinkle infected plants. Successful grafts have been made to various species of Potentilla and to Godetia but no symptoms induced. In 1939 normal and virus infected strawberry plants were successfully inarched to mosaic-infected and normal raspberry plants respectively, but the results of this experiment are not yet available.

IV.—Future Programme.

Further work will be directed along the following lines :

(1) The discovery by routine testing with indicators, and the maintenance under vector-proof condition, of adequately virus-free nuclear stocks of a wide selection of named varieties in addition to Royal Sovereign.

(2) The classification of these varieties by artificial infection tests and field trials into two alternative groups each comprising early, mid-season, and late varieties :

Group 1, virus susceptible varieties with high symptom expression, i.e. roguable.

Group 2, virus resistant varieties of the symptomless-carrier type, i.e. partially or nonroguable.

(3) The investigation of methods for the maintenance of vigorous commercial stocks of varieties in Group 2.

(4) Co-operation with the plant-breeder in the production of new seedling varieties for the above groups capable of more efficient control of virus disease.

Group 1, varieties with improved symptom expression and/or resistance to the insect vector.

Group 2, varieties with increased resistance (immunity if possible) to the viruses.

(5) The etiological studies will be continued in so far as they implement the above practical horticultural issues.

Summary.—The progress of a research programme in strawberry virus diseases from 1932 to 1939 inclusive is reviewed with special reference to proposed future developments.

References.

Harris, R. V. (1933). "The Strawberry 'Yellow-edge' Disease." *Journ. Pom. and Hort. Sci.*, **11**, 56-76.

——— and Hildebrand, A. A. (1937). "An Investigation of Strawberry Virus Diseases in Ontario." *Canad. J. Res.*, **15**, 252-80.

Massee, A. M. (1935). "On the Transmission of the Strawberry Virus 'Yellow-edge' Disease by the Strawberry Aphis, together with notes on the Strawberry Tarsonemid Mite." *Journ. Pom. and Hort. Sci.*, **13**, 39-53.

Rogers, W. S., King, Mary E., and Massee, A. M. (1939). "Results of Researches in Strawberry Growing." *Sci. Hort.*, **7**, 71-84.

A REVIEW OF RESEARCH ON CANE SPOT OF LOGANBERRY AND PHENOMENAL BERRY

By R. V. HARRIS, A. B. BEAKBANE and M. H. MOORE

Etiology.—Observations during the seasons of 1931 to 1934 inclusive* indicated that the seasonal cycle of the fungus (*Elsinoë veneta*) on Loganberry and Phenomenal Berry differs in certain fundamental respects from that on raspberry,† in particular the time of the maturing of the ascocarps and the relative importance of the leaf spot phase. Experiments in direct control have shown that the

* The observations and records in 1933 and 1934 were made by Miss J. B. Hamond.

† *Journ. Pom. and Hort. Sci.*, **9**, pp. 73-99.

optimum schedule for raspberries is not adequately effective for Loganberry or Phenomenal Berry. More detailed studies will be made on the special experimental plot planted in 1938 (Experiment 4. below).

Experiments in Control.

Experiment 1 (1931-5) *Spraying.*—This was a combined trial, in collaboration with the Insecticides and Fungicides Section, on the control of Cane Spot and Loganberry Beetle (*Byturus tomentosus*). The results of spraying at each of the following stages were compared :

(1) " Delayed-dormant " (March), as for raspberries.
(2) " Pre-blossom " (May), as for raspberries.
(3) " Beetle-control " (late June).

The results of (1) were consistently negative. Appreciable, though not complete, control was, however, obtained with (2) and (3), the combined applications giving the best results. In addition to the main trial a few hills were sprayed immediately after cropping, and the results were sufficiently encouraging to warrant more extended trial.

Of the fungicides used, promising control was obtained both with Bordeaux mixture and lime-sulphur. The use of either of these fungicides at the beetle-control stage was later discontinued owing to the marking of the fruit by Bordeaux mixture, and the objection to canning berries sprayed with lime-sulphur owing to a deleterious action of the sulphur deposit on cans.* A proprietary copper spray of known composition was therefore substituted at this stage, with satisfactory results. In all cases the fungicide was combined with Derris for beetle control.

Experiment 2 (1932-4). *Methods of Training.*—Early observations in growers' plantations indicated a relationship between the disposition of new bine relative to fruiting bine and the intensity of Cane Spot attack. This experiment provided confirmation of this important point, showing conclusively that considerable control of Cane Spot could be obtained by the adoption of an appropriate system of training the bines.

Experiment 3 (1935-). *Combined Training and Spraying.*—This was primarily a pomological trial to compare the cropping of Loganberry with Phenomenal Berry under various training systems. To obtain the maximum information an optimum control of Cane Spot was essential, and to attain this, having regard to the limited information then available, subsidiary provision was made to compare the efficiency of two spraying schedules in any one season. By a progressive elaboration, or " stepping up " of the spraying programme from the simplest possible, and in combination with appropriately modified training systems, a high degree of control of Cane Spot has been obtained.

In 1939 this elaboration had reached the stage when the following schedules were compared :

A. Pre-blossom and beetle-stage applications.
B. Pre-blossom, beetle-stage and post-cropping applications.

As in previous years a proprietary brand of " colloidal " copper fungicide (combined with Derris) was used at the beetle-stage, and Bordeaux mixture for the other applications.

Records on the incidence of the disease in 1939 indicated that the attack was in general less severe than in 1938. As in previous years the Loganberry was much more severely affected than Phenomenal Berry. Infection was lightest on plants trained by the " Fan method " (*E. Malling Res. Sta. Ann. Rep. for 1938*, p. 99, method iv) and most severe on those trained at 6 ft. apart on double wires (*ibid* method iii). The spraying schedule B was more effective than A.

Experiment 4 (1938-). *Combined Training and Spraying.*—As information from the previous experiment was necessarily limited by the absence of consistently unsprayed plots, the present experiment was designed and planted in 1938 primarily to determine the simplest and most economical schedule of control measures for commercial plantations.

Two training methods are combined with the following spray treatments :

A. No spray.
B. Post-cropping spray.
C. Pre-blossom spray (May).
D. Pre-blossom and beetle-stage.

The fungicides and insecticide applied so far in this experiment are the same as those used in Experiment 3. In 1939 the complete spraying schedule was applied. Records of the incidence of the disease indicated, even at this early stage of the experiment, a marked reduction on those sections receiving spray treatments B and D, the effect being most evident with B. A differential effect of the training treatments was also shown.

Summary.—The development of a research programme on the commercial control of the Cane Spot Disease of Loganberry and Phenomenal Berry (*Elsinoë veneta*), from 1931 to 1939, inclusive, is outlined.

* See *E. Malling Res. Sta. Ann. Rep. for 1938* (1939), p. 262.

ENTOMOLOGY

NOTES ON SOME INTERESTING INSECTS OBSERVED IN 1939

By A. M. MASSEE

1. **Nut Weevil** (*Balaninus nucum* L.).—Although the nut weevil is always common in the nut plats in the Malling district, it is usually not plentiful enough to cause any serious harm. In 1937, however, it became far more abundant than usual in a cob nut plantation at East Malling. The infestation has increased steadily since that time, and when the cob nuts were gathered in September, 1938, about 75 per cent. of the crop was found to be infested with weevil larvae.

A number of larvae were collected and were kept in a tin containing damp sand. Adults emerged during the first week of February in the laboratory. Under natural conditions the weevils hatch out in April, after passing the winter in the larval state. One possible explanation of the apparent increase of the nut weevil in recent years is that more and more nut plantations are being grubbed each year, and in consequence the weevil population migrates to the few remaining nut plantations in the vicinity. However, the wild hazel is also a host plant of the weevil, and since this plant grows freely everywhere in the district, there is plenty of food left for the weevil, even in the absence of the cultivated nut.

2. ***Gnorimus nobilis*** L.—The larva of this interesting, and extremely local, green chafer beetle feeds upon the wood mould of old, partially decayed fruit trees, more especially the plum. A few larvae were found in a decayed plum tree at East Malling in 1928, but it has not been seen again until this year, when larvae were found in numbers in the wood mould of an old Keswick Codling apple tree at East Malling. Some of the larvae were boring into the heartwood of the tree, but the majority seemed to prefer the decayed portions. It is evident that this insect has been breeding in the tree for several years, and the grower informs me that he has noticed for a number of years a green woodpecker " working " the tree trunk to procure the larvae.

Another species of wood-boring beetle, *Sinodendron cylindricum* L., also occurs in the same tree trunk.

3. **Wireworm Infestations in Hop Gardens.**—Several reports of wireworms causing considerable damage to the roots of hops have been received from hop-growers at Maidstone, Tonbridge and Paddock Wood.

It is well known that wireworms are partial to hop roots—especially the young hills—but normally the damage caused to the plants is not serious. The damage was so severe, however, in the hop garden at Paddock Wood that the young bines began to wilt by the second week of May. Examination of the soil around the hills disclosed the presence of a large number of wireworms feeding upon the young roots. Similar damage was noted at Maidstone and Tonbridge but the wireworm population was not so high.

All the larvae reared in the laboratory proved to be *Agriotes lineatus* L. one of the familiar pea and bean weevils, but there is little doubt that other species were present also.

Crude commercial naphthalene applied at the rate of 4 cwt. per acre, around the hills only, and lightly forked in, proved very effective in three hop gardens. It must not be assumed, however, that this treatment is always effective on a field scale.

4. ***Scymnus punctillum*** Wei.—*Scymnus punctillum* Wei. is a minute, shiny, black clavicorn beetle, measuring $1\frac{1}{4}$ mm. in length, and it is contained in the same family as the ladybird beetles. It is frequently overlooked because of its minute size, but it is, nevertheless, not uncommon in many hop gardens during the summer months. It is predaceous in its habits, and its larva feeds upon the Hop-Damson Aphid and other small insects and mites associated with the hop. This beetle also frequents blackthorn bushes where it may be met with each year in the Malling and Paddock Wood districts.

5. **Short-Cloaked Moth** (*Nola cucullatella* L.).– The caterpillar of this delicate little moth feeds on the foliage of various kinds of fruit trees and on the whitethorn, and recently it has been observed not uncommonly feeding on the foliage of Myrobolan at East Malling. The caterpillar is reddish-brown, clothed with greyish hairs ; the central line and spots on the back are white.

The caterpillars hatch out in August, from eggs deposited on the leaves in July, and after feeding for a short period, go into hibernation until the following spring. The winter is usually spent on the tree, under loose bark and in the crevices. They start feeding again in May on the upper surfaces of the leaves. The adults emerge in June and July.

While this insect cannot be regarded as a pest, it is of interest to note its association with cultivated fruits.

6. **Light Emerald Moth** (*Metrocampa margaritaria* L.).—The caterpillar of the Light Emerald Moth is more common in the fruit plantation than is generally supposed, and this is doubtless due to the fact that the nature of the injury caused to the shoots of apple, plum, etc., is very similar to that made by the Clay Coloured Weevil, and thus it is often mistaken for the latter insect.

The caterpillar varies in colour from purplish-brown to greenish-brown, and it is sometimes marked with ashy-grey. It feeds on the foliage of apple and other fruit trees from September until leaf-fall. It then removes itself to the young shoots, and feeds upon the outer layers of the bark, eating out little patches up and down the stem. The larva is fully fed by the middle of May. The adult occurs in June and July.

The Light Emerald Moth caterpillar was found commonly in an apple orchard at Rainham, Kent, in March by tree pruners, who first noticed the damage to the young growths, and then discovered the caterpillars eating the roots.

This insect rarely becomes common enough to cause any serious harm to established trees, but sometimes causes trouble in the nursery.

7. ***Argyroploce urticana*** Hübn.—Although the caterpillar of this Tortricid moth usually feeds upon whortleberry, honeysuckle, birch, and other vegetation, it is also partial to the strawberry, and occurs commonly on this host at Westerham and in the Maidstone district in the month of May.

The caterpillar is dark red-brown, with a black head. The damage caused to the strawberry plant is very characteristic. It grows through the stalks of the leaves and the flower trusses causing considerable injury.

Although this Tortrix is very common and widespread, it is found only occasionally on strawberry, a very fortunate fact in view of the nature of the damage caused to the plant.

Derris dust is an effective remedy against this insect provided it is used directly the first sign of damage is detected in the field.

8. **Raspberry Moth** (*Lampronia rubiella* Bjerk.).—The Raspberry Moth is one of the most important insects associated with the raspberry, and most growers are familiar with the red grub, which lives and feeds within the young growths of the laterals. In recent years this pest has been found on wild and cultivated blackberries, and more recently it has been noted to be very abundant on loganberry. Two very bad infestations were reported, from Cranbrook and Maidstone. The red grubs were first noted during the last week of April, when a number of wilted lateral growths were removed and examined. The grubs were very numerous, and 20 per cent. of the young laterals were affected on some plants. The infestation was more severe towards the tips of the shoots.

It is evident that the loganberry is a very favourable host plant for this pest, and it seems likely that it will spread to other loganberry fields in the neighbourhood of Maidstone and Cranbrook. Growers, therefore, are advised to look out for this pest and destroy it, before it has time to become thoroughly established in their loganberries.

9. **Psychid Moth** (*Luffia ferchaultella* Stephens).—The caterpillar of the Psychid Moth lives in a little cigar-like case made of lichen, which is very similar in appearance to that of the well-known case-bearer caterpillars so commonly found on fruit trees.

Enquiries are received regularly each year from various parts of Kent concerning this insect, which may be found commonly during most months of the year, attached to hop poles, spile fences, gate posts, etc. The caterpillar actually feeds upon a species of lichen (*Lecanora varia*), and does not (as the grower frequently assumes) cause any damage to fruit trees and hops. The small moth of this case-bearer is a wingless species, and it is parthenogenetic. It passes its entire existence within the larval case. The adult emerges in August and deposits her eggs within the old larval case.

An interesting report describing the habits of this moth has been published recently by McDonogh.*

10. ***Triphleps laevigata*** Fieb.—A number of species of Anthocorid bugs occur on the foliage of hops and fruit trees during the summer months. The whole group is predaceous, feeding upon aphides, and other small insects and mites which feed upon the leaves. These bugs have sucking mouth-parts, and frequently cause annoyance to fruit pickers by piercing the flesh of hands and arms with their needle-like proboscis.

Another species must be added to those already recorded, since *Triphleps laevigata* Fieb., a species new to Britain and closely allied to the more common *Triphleps minuta* L., has been found commonly in the hop garden at East Malling. It has been observed feeding upon the Hop-Damson Aphis, but unfortunately it is not plentiful enough to reduce materially this well known hop pest.

11. **Strawberry Tarsonemid Mite** (*Tarsonemus pallidus* Banks).—The Strawberry Tarsonemid

* R. S. McDonogh. *Journ. Animal Ecology, 1939*, 8, 10-28, 3 figs.

Mite, in common with many other pests, is more prevalent some years than others, and it seems likely that seasonal conditions account for this fact.

In 1938 and 1939 severe infestations were noted at Westerham, Ulcombe, and in the Maidstone district. Less severe infestations have been noted in other parts of Kent, and it seems likely that the mite will be generally common in 1940 provided the climatic conditions are suitable.

It is of interest to record that all the bad attacks were confined to the variety Royal Sovereign. In one field Royal Sovereign and Western Queen were growing side by side, but the Sovereigns alone were infested with mites. *Fragaria chiloensis*, which is grown at East Malling for experimental purposes, and has been regarded as being highly resistant to mite attack, was noted to be badly infested in August. The crowns of many of the plants were affected and the young leaflets dried up before expanding. Another point of interest is the fact that the mites do not confine themselves to the young unopened leaflets—as is usually the case—but they occur freely on both surfaces of the older leaves, even in bright, sunny weather.

12. **Strawberry Aphides.**—Although the common strawberry aphis (*Capitophorus fragariae* Theo.) is usually present wherever strawberries are grown in Kent, it is of considerable importance to find that it is not equally prevalent in all parts of the county. For example, a very severe infestation was observed at Orpington in May, where the aphis population was so numerous, that many of the plants were crippled and sticky with honey-dew. The crop was so seriously affected, that after picking, the grower wisely decided to plough up the field.

A very different story may be told of the strawberry growing area around Ulcombe. The aphis population proved to be extremely low on most farms, and odd specimens only could be found after a prolonged search.

In general it may be said that the aphis population was below normal in most parts of Kent.

The potato aphis (*Macrosiphum gei* Koch), which also feeds upon the strawberry and may be found in small numbers in most strawberry fields in the summer months, must not be regarded as an insect of economic importance, since it does not cause any direct damage to the plant, and it is not a vector of any of the recognized virus diseases of strawberry.

13. **Red Leaf Aphis** (*Anuraphis crataegi* Kalt.).—Two very severe infestations of the Red Leaf Aphis were noted, one at Linton and the other at East Farleigh. The damage on each farm was very serious and of the several varieties of apple attacked Bramley's Seedling suffered most damage.

Although this aphis had been noted on both farms in previous years, it was not common enough to worry about, and it did not appear to increase to any extent until 1938 when it became more widespread on both farms. The damage caused by this aphis is very characteristic. The leaf is curled in a lateral manner, and the colour changes to a bright red or sometimes yellow and red. The injury is caused in May and June, a period during which the aphides increase very quickly. The winged stage is reached by the third week of June, when by this time all the damage has been done for the season. There is one curious point in regard to the winged form. It does not appear to migrate to another host, as is common with many species of aphides, but it remains on the apple and deposits its eggs on the trunks and main branches in July. They are invariably laid in cracks and crevices and under loose bark. The eggs are never deposited on a smooth surface, or on the young growths.

The egg is elongate-oval and rounded at each end, one end being slightly more tapering than the other. It is deep brownish-black, glabrous and shining. The newly laid eggs are of a lighter brown, but they soon darken. They are deposited in large masses in an irregular manner, and measure 590μ × 280μ (average of 12 ova).

14. **Raspberry Cane Midge** (*Thomasiniana theobaldi* Barnes).—This midge has previously been considered to attack only a few varieties of raspberries, and to have a very local distribution.

Small numbers have occurred regularly at East Malling for several years. A more detailed survey in September, 1939 showed that many varieties of raspberry were attacked, some seriously. Some years ago it was noticed that there appeared to be an association between the midge and raspberry cane blight (*Leptosphaeria Coniothyrium* (Fuck.) Sacc.).—In the recent survey midge larvae could only be found on canes already attacked by cane blight where the rind had split.

The reddish maggots live under the rind, only causing serious damage when very numerous, then the symptoms may be branching of the canes, or in extreme cases death, due to the rind peeling off. There are said to be two broods each year. The first flight of midges occurs in May and June, with a second brood in July and August. The presence of larvae in September seems to confirm the occurrence of a second generation.

Badly infested canes should be cut out and burnt before the maggots leave them to pupate in the soil. Hoeing around the canes might also help to control this insect.

The writer is indebted to Dr. G. H. L. Dicker for the notes on this midge.

15. **St. Mark's Fly** (*Bibio hortulanus* L.).—The maggot stage of the St. Mark's Fly is very similar in appearance to the larval stage of the Leatherjacket, and in consequence enquiries are received

about it each spring. Recent correspondence from Strood and Gravesend suggest that it is very common in these Medway towns. The maggots are detected in the soil when gardens and allotments are being dug up in the spring.

As a matter of fact this insect is not injurious to agricultural crops, its food being confined to decayed vegetable matter. The adult male fly is black, the female, however, has a black body, while the head and thorax are red. This species is considerably larger than the common house fly.

16. **Leatherjackets.** Recent enquiries show that leatherjackets have been causing severe injury to strawberries in various parts of Kent. The districts of Tonbridge, Sevenoaks and Tenterden appear to be the most seriously affected. The attacks have been mainly confined to the crowns of young plants, causing serious injury and often death. Newly planted fields appear to be most subject to attack, especially when planting is left until the spring months.

Fortunately the Paris green and bran bait is very effective against this pest, especially when the bait is applied immediately the first indication of damage is detected. The bait should be applied just before or after a light rain, about the end of April. Excellent control was obtained at Tenterden and Sevenoaks with one application of bran bait applied early in May.

17. **Mediterranean Fruit Fly.** (*Ceratitis capitata* Wied).—Although the Mediterranean Fruit Fly has been introduced into this country in imported citrus, on several occasions, there does not appear to be a record of the fly actually breeding in this country under natural conditions.

It is of interest, therefore, to describe briefly the rearing of two specimens from apple, though it must be emphasized, that the chances of this insect establishing itself in this country are remote, and there is no reason to assume another potential pest is in our midst.

A number of Cox's Orange Pippin apples, gathered from a tree growing in a small garden at South Harrow, Middlesex, were found to be infected with small, whitish maggots. The fruit was sent to East Malling with a request for information about the insect infesting the apples, and suggestions for control. An examination of the fruits disclosed the presence of small white maggots tunnelling in the flesh. No trace of damage could be seen on the surface, but one or two soft places just under the skin suggested that the fruits had been slightly bruised. On cutting open the apples it was evident that the soft areas had been caused by maggots feeding on the flesh just under the skin. The type of injury caused to the fruits is characteristic of that made by the Apple Fruit Miner. Two specimens were bred out, however, and they proved to be a male and female of the Mediterranean Fruit Fly. Although several more maggots were found in the fruits, they did not mature and no more flies hatched out. Eventually the fruits were destroyed.

The owner of the garden states that he has four trees, three apples and a pear. Of these only the Cox fruit was infested, some of the fruits falling prematurely as the result of attack.

All the fruits in the garden have been collected and destroyed, and the soil under the trees has been treated with an insecticide as a precautionary measure.

It may be significant that a greengrocer's shop is situated quite near the garden, and it is reasonable to suggest that the flies came from this source, and temporarily established themselves on the Cox fruits growing in the garden.

Summary.—Brief notes are given of some seventeen insects found on fruits in 1939.

The Tortrix caterpillar, *Argyroploce urticana* Hübn. occurred more commonly than usual, and the Raspberry Moth *Lampronia rubiella* Bjerk. has been causing serious injury to cultivated blackberries. The Red Leaf Aphis, *Anuraphis crataegi* Kalt., is widespread on two farms in Kent, and must be considered an important pest. Mention is made of the Mediterranean Fruit Fly being bred from apples growing in a private garden in this country.

DIPPING OF STRAWBERRY RUNNERS BEFORE PLANTING

By A. M. MASSEE and R. M. GREENSLADE

It has been emphasized several times in recent reports that the natural spread in the field of Yellow-edge and Crinkle virus diseases is caused by the strawberry aphis (*Capitophorus fragariae* Theo.), and that every effort should be made to eliminate this insect from the plantation. One of the surest means of achieving this object, is by dipping the plants or runners in a solution of soft soap and nicotine before planting.

Although the actual process of treating the plants is quite simple, from time to time reports have been received of severe injury or even death of strawberry plants after dipping them in soft soap and nicotine. Fortunately reports of damage are not very numerous, and at present it has not been

possible to determine the cause of injury. Soft soap at 8 lb. per 100 gallons and nicotine at 8 oz. has been used extensively at the Research Station and on commercial farms, as a matter of routine, without any trace of injury to the plants.

In order to test the possibility of soft soap being injurious, a trial has been carried out with one-year Royal Sovereign plants, which had been raised under glass, and were thus in a tender, sappy condition, and presumably more subject to injury than plants raised in the open. The plants were dusted with flowers of sulphur on 3rd May (six days before the dipping trial began), to check the spread of mildew—a procedure always carried out when strawberries are raised under glass.

Two series of soft soap solutions were prepared, one from a well-known commercial soft soap (a potash soap), and the other from caustic soda and oleic acid. The concentrations were made up as follows :

Soft soap, 4, 8, 12 and 16 lb. per 100 gallon.
Home-made soap, 0·2, 0·4, 0·6 and 0·8 per cent.

All solutions contained 0·05 per cent. of nicotine (8 oz. per 100 gallons).

Six plants in pots were used for each concentration. Each plant was completely immersed for about ten seconds and moved about to ensure wetting every part of the plant. After draining off excess liquid they were placed in a sunny position and kept under observation.

On the following day black markings appeared on the leaf stalks and young leaves of the plants treated with the highest two concentrations of both series.

The plants were examined from time to time and two weeks after dipping the following notes were made :

Control plants, untreated.

Slight bronzing of leaves of all plants. (A characteristic apparently peculiar to this strain of Royal Sovereign.)

Home-made Soap series.

0·2 per cent. No injury recorded.
0·4 per cent. Slight leaf stalk injury to two plants, but not affecting growth.
0·6 per cent. } Some injury to leaf stalks, but growth only slightly checked ; leaf bronzing
0·8 per cent. } more severe than controls.

Soft Soap series.

4 lb./100 gallons. No injury.
8 lb./100 gallons. No injury.
12 lb./100 gallons. Edges of young leaves scorched on one plant.
16 lb./100 gallons. Edges of young leaves scorched on four plants. No injury to leaf stalks in this series, and leaf bronzing no worse than on the control series.

Ten days later all the plants of each series had grown considerably and no difference could be seen between any of the treatments, so that the injury was evidently not of a permanent nature.

The results of this small trial confirm the opinion of the writers that it is perfectly safe to dip strawberry runners in a solution of soft soap, 8 lb. and nicotine, 8 oz. per 100 gallons of water, and this practice should be adopted whenever possible before planting.

As already stated the practice of dipping runners in a solution of soft soap and nicotine is carried out as a matter of routine at the Research Station and on the farms of many commercial strawberry growers, and is strongly recommended in districts where aphis is known to thrive on young plants.

No special technique of dipping is required. Simply plunge the whole of the plants (including roots) into the solution of soap and nicotine, and remove them as soon as they are completely wetted. If the runners are tied up in bundles, the strings should be cut, in order that the centre plants may be thoroughly wetted. On removal they are ready for planting, but to ensure ease of handling it is best to allow the surface moisture to evaporate.

Further details are given in the Annual Report for 1938.*

Summary.—Occasional reports of injury to strawberry plants have been ascribed to the soft soap used in sprays against Strawberry Aphis, *Capitophorus fragariae* Theo. In order to test this, plants were immersed in solutions of commercial soft soap and of soap prepared from oleic acid and caustic soda both containing nicotine. No permanent injury resulted from concentrations up to 0·8 per cent. of soap, which is double that normally recommended.

* Greenslade, R. M., and Massee, A. M. (1939). "Suggestions for Control of Strawberry Aphis." *E. Malling Res. Sta. Ann. Rep. for* 1938, A22, 250-2.

INSECTICIDES AND FUNGICIDES

A BRIEF REVIEW OF RESEARCH WORK AT EAST MALLING ON THE CONTROL OF APPLE SCAB

By M. H. MOORE

For the past fourteen years the development of a satisfactory spray programme for Apple Scab control has been studied in very great detail.

The results of a large number of spraying trials both here and elsewhere have brought out one point above all others. It is that Apple Scab can be satisfactorily controlled by the standard fungicides—lime-sulphur and Bordeaux mixture—that have stood the test of time, provided that sprays are applied at certain definite periods in relation to the time of dispersal of the spores that begin the seasonal cycle of infection in spring. In spite of this basic agreement among many different workers, there is divergence of opinion as to the strength of spray that can safely be used in different localities and under different seasonal conditions, and variations in recommendations revolve almost entirely around this point. Much information is available to show that under the conditions of any particular experiment lime-sulphur was safe at such-and-such concentration, while there is probably as much evidence to show that under different conditions lime-sulphur at the same strength was not safe.

This state of uncertainty has led logically to an exploration for fungicides safer than lime-sulphur or Bordeaux mixture in all circumstances, and this important line of work is proceeding in laboratory and field. Up to the present, lime-sulphur has not been dislodged from its position as the standard fungicide for Apple Scab mainly because other sprays so far tested, while showing perhaps greater all-round safety, have scarcely equalled it fungicidally unless used at strengths that would considerably increase the cost of the spray. Moreover, lime-sulphur has proved more valuable than its possible rivals in keeping Red Spider and Apple Mildew in check. Bordeaux mixture has not proved safe on certain apple varieties even at low concentrations, such as 2-3-100, and it does not control Red Spider or Apple Mildew.

A similar line of thought has led to experiments in which certain chemicals were added to the standard spray to increase its safety on the tree. Examples are seen in ferrous sulphate for lime-sulphur or the lime-sulphur-arsenate mixture, and cottonseed oil for Bordeaux mixture. As already stated on page 32, ferrous sulphate did not consistently maintain early promise and it was objectionable to use for it blackened the spray, and cottonseed oil, while showing considerable promise (particularly on stone fruits and pears) is expensive. Moreover, the Bordeaux-cottonseed oil has not yet proved entirely safe on apples.

It is therefore evidently true to conclude that the main problem in the control of Apple Scab, and, indeed, of any other disease susceptible of control by protective spray treatment, is *spray damage*, particularly since the introduction of modern high-pressure methods of spraying. Efforts to solve the problem by adjustments in strength of sprays, by the addition of chemicals to make the standard fungicides safer to use, and by the use of new fungicides, have not so far been entirely satisfactory. The chemical spray, while toxic to the fungus (or the bacterium), may be toxic also to the host. Parasite and host are each members of the plant kingdom and as such tend to exhibit similar reactions varying in degree but not in principle. Hence the aim must be to widen as much as possible the divergence between the limits of tolerance of parasite and host to treatment by chemical sprays.

Thus the problem can be approached through modifications not only in spray fluids but also in host resistance to disease and to spray damage. While the spraying experiments were in progress, it became increasingly clear that the incidence of Scab and of the spray damage resulting from efforts to control it was closely related to such factors as locality, weather conditions, and the soil and its cultural and manurial treatment. The scion variety and the rootstock on which it is worked each contributes to the constitutional build-up of the tree and each thus has its influence on susceptibility or resistance to Scab and to spray damage. As would be expected, the incidence of spray damage was in positive relation to the strength of the spray, other things being equal.

Enough data have already been obtained to show that this second line of approach is essential to further progress, and it will be given increasing attention in the future programme of work. To that end, collaboration between the work of the Insecticides and Fungicides Section and that of Pomology, Physiology and Biochemistry is, and will become, much closer than hitherto. Experiments are already in progress in which the influence of cover cropping, of soil moisture content, and of

manuring on the susceptibility of the host plant to disease and to spray damage, is being studied. Other current experiments are designed primarily to explore the physiological basis of spray damage.

This review is intended to emphasize the principle on which past work has been, and future work will be, based. The principle applies not only to Apple Scab but to the very wide problem of diseases and the protection of plants from them. Investigations on the biology and control of the other diseases mentioned on page 33 will be continued. If a safe, effective and relatively inexpensive spray treatment can readily be found, the ideal has been achieved, but if the same problems inherent in the incidence and control of Apple Scab be encountered, they will be approached in the same way.

Summary.– The problem of spraying for the control of Apple Scab is broadly reviewed on the basis of past experience, and the lines of future work are briefly indicated with particular reference to the nutrition of the host.

HOPS

THE EFFECT OF VARIOUS CULTURAL TREATMENTS ON THE CROPPING OF HOPS

By F. H. BEARD

Introduction.—General reviews of the hop research work at East Malling have been published recently (Beard, 1938 ; Hatton and Beard, 1939).

The results to date of the cultural trials are dealt with in further detail in the present paper, together with suggestions for future work. The object of these trials is to ascertain the effect, on the size of the crop and its quality, of the various cultural practices such as cutting, pulling, and methods of training. There are at present six of these trials under way. With one exception they have been carried out on the most promising of Professor Salmon's new varieties ; these afford wide contrasts in vigour, season, etc., and are therefore very suitable for the purpose. All trials have been conducted on a Butcher work garden with 7 ft. alleys.

Distance of Planting.—Results obtained from a field manurial trial showed that the increase in yield per hill as a result of the wider spacing due to the death of adjacent hills was sufficient to mask any manurial effect that might be present (Amos and Hoblyn, 1928). The influence of the distance between the hills was therefore one of the first problems to be investigated.

The first distance trial was carried out on the early variety L21, which is a good cropper for an early variety, but makes only moderate bine growth, with short " croppy " laterals. There were three distances between the hills in the rows (9 ft., 6 ft., 3 ft.) combined with 1, 2 and 3 bines per string. This trial was concluded in 1936 and a report published (Beard, 1937). The yield per acre increased greatly as the distance between the hills decreased. The average crop for the three distances for the six-year period was 16·59, 21·00, and 24·11 cwt. per acre. The yield per hill increased with the distance between the hills, but the increase was insufficient to compensate for the fewer hills. The experiments were continued using the variety Brewer's Favourite (OP21). This is planted at our normal distance of 7 ft. × 7 ft. and also at 7 ft. × 3 ft. 6 in. It is very different from L21 as it is late in season, and produces much lateral growth relatively late in the season. Although the closely planted hills have given the heavier crop, the average increase of 2·61 cwt. per acre is less than the increase obtained with L21. In one season (1936) the increase was too small to be significant. The closely planted hills made such a dense " wall " of bine that efficient spraying was difficult, so from 1938 these hills have had only one bine per string.

A third variety tried was P13 ; this early variety makes a very attractive sample when dried, but is a very poor cropper. It did not yield any increase in crop by close planting ; both normal and close planting gave very low yields. This lack of response may be attributed to the habit of growth. P13 makes quite strong growth, but this bears laterals which are characteristically unfruitful.

Professor Salmon has raised from the New Mexican Wild hop a number of seedlings which are remarkable for their very great vigour. It is obvious that they are somewhat cramped under normal conditions and liable to get "housed in". As some of these hops have a very high P.V. and also are enormous croppers it is desirable to discover a satisfactory method of growing them. It is possible that they can make full use of very wide spacing, and this is being tested on OI47, in conjunction with variation in the nitrogenous manuring. The variety is not yet fully established but one season's

records show that the plots with very wide spaced hills (9 ft. apart in rows) yielded only slightly less than those with 6 ft. spacing.

Number of Bines per string.—While there have been differences in cropping due to the number of bines per string, they have not been great, and have varied from year to year. With L21 at 9 ft. apart in the rows, one bine per string gave significantly lower yields in five years out of six, but there was no difference between 2 and 3 bines. At 6 ft. apart the difference between 1 and 2, and 2 and 3 bines, was only once significant, but there was a significant difference between 1 and 3 bines in four years out of six. With the hills at 3 ft. apart the cropping increased slightly with the number of bines but was significant in only one season.

With a vigorous variety (OV7) the crop from the plants with 1 bine was less than from those with 2 or 3 bines, in two out of three seasons. One bine per string gives much better developed cones and less tangled bine than either 2 or 3 bines. This is most marked in seasons of poor cone development, and with closely planted hills.

Pulling and Cutting.—So far we have obtained no evidence that operations which affect the vigour of the trained-up bine influence the cropping to any extent. With Brewer's Favourite in only one season out of five (1939) has there been any difference in cropping between the hard and lightly pulled plots and then the difference was only small and largely accounted for by the heavier cropping of the wide-spaced and lightly pulled plots. Hard and light cutting of Fuggle hills has given no differences over a five-year period.

More recently a combined cutting and pulling trial has been laid down with Quality Hop (0063). The hills are cut in December, February and March ; on half the plots the first bine is trained up, while the others receive the normal pulling. Although there have been big differences in the forwardness of the bine when measured at the end of May, the plots even up as the season progresses and at picking time they are indistinguishable. So far (two seasons) all treatments have yielded equally good crops.

Problems arising out of the use of Picking Machines.—When hops are to be picked by machine it is desirable that they should be free from dense " heads ". To a certain extent these can be prevented from forming by hard pulling, but it is not always possible to tell which bine to put up early in the season. Good growing weather may cause a bine of only moderate vigour at training time to become too strong in quite a short while, so a method of checking excess vigour later in the season would be an advantage.

Our experiments have shown that " stopping " the bine in the region of the lacing string prevents the formation of heads. It does, however, also reduce the yield. Stopping at the top wire does not prevent the formation of heads. It is intended to plan a new trial with a strong growing variety to see if modifications of the stopping technique (say stopping at breast wire) will prevent " heads " forming and cause no reduction in yield.

Experiments carried out at Wye some years ago showed that when the bine is cut just above ground level at picking time (as in " pole work " gardens) the yield is reduced (Burgess, 1920). It is therefore possible that when the bine is cut at about 3 ft. from the ground for machine picking the vigour and cropping of the hills may be affected. This is now being tested on a small area of Fillpocket. Should the cutting of the bine cause a reduction in vigour, heavier nitrogenous manuring might compensate.

Discussion of Results.—Our experiments have demonstrated the very great effect of distance on both the yield per acre and the yield per hill. They show the necessity of maintaining a full plant in field trials if reliable results are to be obtained.

With varieties of normal vigour on good soils close planting will give excess of bine growth with consequent difficulty in controlling disease, and in some seasons poorly developed cones. These disadvantages can be largely counterbalanced by training only one bine up each string. Close planting is likely to be most profitable on soils where bine growth is usually slight, and with weaker varieties with short " croppy " laterals.

Close planting has given the biggest increases in cropping in years of heavy general crop ; this is in contrast to the results obtained from some early experiments at Wye (Burgess, 1920).

The number of bines per string has had very much less effect on the yield than distance of planting, but on an average one bine gives lower yields than either 2 or 3 bines. It must be remembered that in practice there will be some losses in bines after training, and with one bine per string blank strings will occur. Thus, in the OV7 trial the average number of bines per string for a three-year period was 0·95, 1·84 and 2·70 bines per string for three 1, 2 and 3 bines per string plots respectively. There is no practical difference in cropping between 2 and 3 bines per string. One bine per string can only be recommended where the hills are closely planted, when it will give almost as heavy yields as two bines per string, without the risk of excess bine growth and poor cone development. There appears to be no advantage in training up three bines per string even with wide spacing. With two bines

per string blank strings are unlikely and there will be little if any reduction in yield from an occasional single bine string. One bine per string gives better developed cones at all distances of planting and can therefore be recommended for gardens in which cone development is often poor owing to excess bine. The improvement in cone size is most marked in seasons of generally poor development.

Conclusions.—The heaviest crops consistent with reasonably well-developed cones result from close planting combined with one bine per string.

Our cutting and pulling experiments show that while these treatments affect the vigour of the bine produced, there is no corresponding influence on the yield; late weak bines give as good crops as the more forward and stronger bine. It is necessary to distinguish between weak bine produced from vigorous hills by means of cutting or pulling, and slight bine from weak hills, that will naturally give poor yields.

Late and hard cutting reduce the pulling required before the strings are furnished.

If the later and weaker bine is trained up there is less risk of excess bine growth and consequent difficulty in controlling disease. It is easier to stimulate backward bine by quick acting nitrogenous manures, than it is to check over vigorous growth during the season.

No cultural treatment so far tried has had any influence on the number of bushels of green hops needed to give a hundredweight of dried hops, or on the resin content. These appear to be varietal and seasonal characters.

Although it will be necessary to continue the pulling and cutting trial for a few more seasons before drawing any final conclusions, it seems unlikely that the treatments can have any big influence on the yield. Future cultural trials will chiefly consist in applying our results to secure the optimum returns from commercial varieties and any new varieties of promise which arise from time to time. The new hybrids raised by Professor Salmon have such a wide range of vigour and character of growth that each presents a special problem. Thus the very vigorous and heavy cropping New Mexican seedlings are obviously rather cramped under normal conditions and are likely to get "housed in". To obviate this, wide spacing and reduced nitrogenous manuring are being tested on OI47. Another way of reducing the risk of "housy" bine would be to increase the height of the wirework. The present height was the limit to which sprays could reach, but with modern power spraying this limit no longer obtains, and it is likely that some existing commercial varieties may benefit from higher wirework.

Although the number of bines per string has been found to have only a slight influence on the yield, it is quite likely that the number of strings per hill (in "Butcher" work) may have a greater influence. For instance, very wide planting with four strings to a hill may give better results than closer planting with three strings per hill. This will be tested directly material is available.

There seems to be some evidence that under our soil conditions drought is a limiting factor in certain years. The effect appears to be most marked on the Fuggle and the early seedling varieties. The effect of irrigation will be tested as occasion arises.

Summary.—The results to date of several trials are reviewed and the lines of future work indicated.

Distance between the hills has had a great influence on the yield, whilst the effect of the number of bines per string has been much less. Both distance and number of bines influence cone development.

Pulling and cutting treatments which vary the vigour of the trained bine have had no effect so far on the yield.

The methods of "stopping" tried have prevented the formation of "heads", but have also reduced the crop.

Future trials will include modifications of the stopping technique, the effect of the number of strings per hill, and irrigation.

References

Amos, J. and Hoblyn, T. N. (1928). "Manurial Trials with Hops." *Rep. E. Malling Res. Sta. for 1926-7, II Supplement*, 165-71.

Beard, F. H. (1937). "Cultural Trials with Hops. II. The Effect of Distance of Planting and Number of Bines. A Final Report on the Trial with the seedling L21." *Rep. E. Malling Res. Sta. for 1936*, **A20**, 117-25.

——— (1938). "A Review of Hop Investigations at East Malling." *Rep. E. Malling Res. Sta. for 1937*, **A21**, 161-5.

Burgess, A. H. (1920). "A Short Account of Investigations carried out at Wye College in connection with Hop Production." *Journ. Institute of Brewing*, **26**, 429-48.

Hatton, R. G. and Beard, F. H. (1939). "A Report of Hop Research Work at East Malling Research Station." *Journ. Institute of Brewing*, **45**, 556-9; also *Kent Fmrs' Journ.*, **46**, 162-5.

Section IV

*BULLETINS FOR FRUITGROWERS**

POMOLOGY

PLUM GROWING IN THE LIGHT OF RECENT RESEARCH

A SUMMARY OF STAFF TALKS GIVEN AT THE ANNUAL MEMBERS' DAY HELD AT EAST MALLING RESEARCH STATION ON AUGUST 31st, 1939

By N. B. BAGENAL

Introduction.—About one-sixth of the total acreage under fruit in this country is at present devoted to growing plums. The varieties most commonly grown such as Czar, Victoria, Pershore and Purple Pershore are cooking plums, and with the possible exception of Victoria have little distinctive flavour when ripe. Hence the outlet for plums in this country in the past has been mainly for cooking, jamming, bottling and canning. Since the last war, however, changes in social life and habits have resulted in a decrease in the demand for plums for stewing or for making into tarts. In recent years, also, there has been a decrease in the demand for plums for jam in favour of the more expensive fruits such as strawberry. The home canning industry is reported to use about 10,000 tons of plums annually, an outlet which in recent years has largely offset the decrease in the demand for plums for jam making. In normal times the public appear to prefer canned pineapples, pears, apricots and peaches to home-grown plums on account of their more distinctive flavour. But under war conditions a decrease in supplies from overseas might bring an increased demand for home-grown plums for jam, bottling and canning, provided sugar were available for processing.

Imports of plums from overseas have increased in recent years in spite of the import duty, and the bulk of these are ripe. This suggests that there is a market for dessert plums which the home industry is largely missing at the present time. The above remarks compiled from a statement kindly supplied by Dr. H. V. Taylor, the Commissioner for Horticulture, show at once the present position of the plum industry in this country and the need for a changed outlook on the part of the home producer.

The following summary of some of our experimental findings on plum culture over the course of the last twenty-five years will, it is hoped, prove useful at this juncture.

Raising Trees on Their Own Roots.—Only a few of the market varieties of plums can be raised easily and economically on their own roots. Out of eighteen we tried to raise in this way at East Malling only three proved ready-rooting, and a further six rooted moderately well. A field trial to compare the growth and cropping of Victoria, Cambridge Gage, Yellow Egg (Pershore), and Cluster Damson (Farleigh) on own roots and grafted on vigorous and dwarfing rootstocks was planted here in 1928 using two-year-old trees. All except Victoria have grown more vigorously on Myrobolan B, the vigorous stock, than on their own roots. Victoria, however, made very much the same size of tree on its own roots as on Myrobolan B. With all varieties Common Plum rootstock had a definitely dwarfing effect. In regard to crop all gave their heaviest yield on Myrobolan B, with the exception of Victoria which cropped most heavily on its own roots. "Own root" trees are by tradition reputed to be on the whole resistant to disease, but in this trial there was a certain amount of bacterial canker and the "own root" trees suffered just as badly and even slightly worse than those on Myrobolan B, whereas trees on Common Plum escaped infection. From what has been said it will be clear that we cannot do without rootstocks for plums, and this brings us to a consideration of the position in regard to them.

Rootstocks for Plums. –Our work up to date on plum rootstocks has revealed the fact that at East Malling all the well-known market varieties will make large regular cropping trees on Myrobolan B and on Brompton. At the same time it has to be recorded that two gage varieties, Oullin's Gage and Comte d'Althan's Gage, have shown incompatibility between stock and scion when worked on Myrobolan B. Brompton has shown no incompatibilities, but unfortunately the quantity of this rootstock available in commerce is quite inadequate to meet the demand for plums as well as peaches.

Moreover, trees on these vigorous rootstocks are definitely slow to come into cropping. What of the rootstocks which produce rather less vigorous trees? Of these Pershore Yellow Egg fills the

* Certain articles in Section III also contain information of direct practical interest to fruitgrowers.

bill for a heavy cropping tree of medium size which comes into bearing a few years earlier than it would do on Myrobolan B. Unfortunately no method has yet been found of making Pershore strike root freely, and so it remains at the post, a sure winner if you can get it away, but an impossibly poor starter. Then there is Marianna, a stock which has produced trees of exceptional cropping capabilities for their size, and one which can easily be raised from hardwood cuttings. Unfortunately there is a tradition among some nurserymen, that trees do not do well on Marianna, and we have had cases of incompatibility with Czar, Damsons and Cherry Plum (Red Myrobolan). But although for this reason it cannot be recommended as suitable for all varieties, Marianna is certainly worth a trial for those varieties with which it is known to be compatible, such as Victoria, Rivers' Early, Belle de Louvain, Pershore, Purple Egg and Giant Prune.

When it comes to the question of dwarfing rootstocks for plums the position at present is that a choice must be made between Common Plum, Common Mussel and Brussels, and that not one of these can be considered by any means the ideal stock for a precocious dwarf plum tree. It can be said in favour of Common Plum that trees grafted on it recover more readily from Silver Leaf than on any other rootstock, and that it is perfectly compatible with Victoria. Czar, Damson and Pond's Seedling cannot be recommended on Common Plum, but in our experiments Denniston's Gage, Cambridge Gage, Belle de Louvain, Pershore, Rivers' Early, and Giant Prune have proved compatible with that rootstock. Common Mussel has not come up to our earlier expectations as a rootstock and shows a tiresome propensity to suckering. All varieties tried on Brussels, with the exception of Victoria, have cropped poorly, and this stock also suckers badly. It will be seen from this that there are still many gaps in our knowledge of dwarfing rootstocks for plums, and we are now engaged in an active search for new and better ones.

In 1933 we planted a nursery trial of some new or little known rootstocks, including some selected St. Julien, Kroogespruin, and Damas, and a local stock known as Michaelmas Prune. Of these the last named and one of the St. Julien selections are the most promising, since they appear to combine compatibility between stock and scion with early cropping and easy rooting.

Framework Grafting Methods applied to Plums.—Meanwhile, until we can find some really quick-cropping stock which will bring a plum tree into bearing in two or three years from the bud or graft, what other ways are there of making a quick change over from the cheap cooking plum to the better quality dessert varieties? During the last six or seven years we have been trying different methods of framework grafting plum trees at East Malling, with some encouraging results. In 1933 we had in mind the possibility of grafting Victoria, a variety susceptible to Bacterial Canker, on to Utility, which is highly resistant to the disease. Victoria scions were whip-grafted on to small laterals, leaving the whole framework of the full-grown Utility tree to convey resistance to the bacterial canker. The results were promising, the grafts taking well, and the two trees grafted giving crops of 88 lb. of Czar and 60 lb. of Victoria respectively in the second season. But the high cost of this method of grafting, which necessitated tying each graft before waxing, rendered it of doubtful commercial value. So in 1938 it was decided to try some less costly framework methods, and a set of established Czar trees were frameworked, using two " cleft " methods, the " stub " and " side ", and two rind methods, the " inverted L " and the " awl ". The Czar plum is grown on a very large scale in England, and it seems to resist spring frost. But in a " plum " year Czar often proves very difficult to sell at a profit, and for this reason it is an obvious case for top-working provided this can be done. We knew that Czar was very difficult to please in the matter of rootstocks, showing a high degree of incompatibility with many of them either when budded or grafted in the nursery, or at later stages in the plantation. So it seemed possible that when used as an intermediate stem-piece in framework grafting Czar might not make what is generally known as a good " mother " to these new dessert varieties. Up to the present there has been no difficulty in this respect. The grafts inserted by the two " cleft " methods took much better than those inserted by the two " bark " methods, and made stronger growths, so strong in fact that some of them blew out in a gale in June after grafting. The difficulty, however, could probably have been avoided by summer pruning before the windy season began.

Silver Leaf did no more than make an appearance the first season, but by the following summer 11 per cent. of the total number of grafts were silvered. The cleft grafts suffered more severely than the bark grafts. This is interesting in so far as the cleft grafts were put on nearly a fortnight earlier than the bark grafts at a time when weather conditions were more favourable for the spores of the Silver Leaf fungus to infect trees through wounds. It must be remembered, however, that these cleft grafts can equally well be put on later when there should be less risk of infection. Another observation was that where a large number of wounds over 2 inches in diameter had been made there was more Silver Leaf on the tree than where only small wounds were present. The seven scion varieties in this trial were Oullin's Gage, Ontario, Jefferson's Gage, Cambridge Gage, Warwickshire Drooper, Monarch and Victoria.

There was no apparent connection between strong growth and blossom bud formation on the

scion shoots. Warwickshire Drooper, for instance, was vigorous and also formed many fruit buds (one tree had sixty-four fruits two years after grafting), while Cambridge Gage made equally strong shoot growth but did not bear many fruit buds and had no crop in its second year.

One other plum frameworking trial is being carried out here which is of interest partly because of the large number of scion varieties included, and partly because of the three "mother" varieties used as intermediates. Two, Czar and Purple Pershore, are widely grown; the third, Utility, having a very poor cropping record, is seldom found in commercial plantations, but it is of interest on account of its comparatively high resistance to bacterial canker.

The twenty-four scion varieties, the names of which are given in the footnote below,* were chosen for their high dessert quality or for quality combined with an unusually early or late season of ripening. The grafts were all put on by one of the cleft framework methods and the percentage "take" of grafts varied a good deal. Seven varieties, namely: Cambridge Gage, Old Transparent Gage, Laxton's Gage, Ontario, Warwickshire Drooper, Oullin's Golden Gage, and Old Greengage, gave a "take" of over 75 per cent., and there was no evidence of complete incompatibility between any of the twenty-four scion varieties and the three "mother" intermediates.

The severe gale of June, 1938, blew out many of the most vigorous and top-heavy grafts. Had we looked ahead these might have been shortened back as a precaution. More grafts were blown out on Purple Pershore than on either Czar or Utility, suggesting that these unions were not quite so strong as the others. The strongest growths came from the grafts of Cambridge Gage, Warwickshire Drooper and Old Greengage, and those which carried the most fruit buds in their second season were Warwickshire Drooper, Giant Prune and Laxton's Gage.

In 1938 very little Silver Leaf was seen, but the next year 14 per cent. of the total number of grafts were found to be silvered. Of grafts put on Purple Pershore 4 per cent. were silvered, on Utility 19 per cent., and on Czar 20 per cent. Differences in Silver Leaf infection were recorded, also among the twenty-four scion varieties, Old Transparent, President, Cambridge Gage, Late Orange, Oullin's, Cox's Emperor, and Laxton's Gage being almost or entirely free, while others were quite badly affected. There appeared to be no connection between the vigour of the shoot growth and the presence or absence of Silver Leaf.

The trial is still young, but it is comforting to be able to report that all the twenty-four scion varieties took quite well on Czar. Whether any cases of delayed incompatibility are going to occur, time alone will show.

Plum Thinning.—Growers and salesmen to-day are agreed on the need for growing good sized plums for market, and we have interested ourselves in this problem. Two experiments have been carried out here in recent years on thinning Victoria plums. In 1930 thinning to 1½ inches apart in June-July was tried against no thinning. Briefly the results were as follows: Fruit from thinned trees was considerably larger than that from the unthinned, much of the fruit from the unthinned trees being small, of poor colour and of little or no market value. Thinning reduced the yield by about 40 per cent. yet the average net return for the fruit from the thinned trees was 1s. 5d. a half-sieve as against 6d. a half-sieve from the unthinned. Whilst wind damage was almost negligible in the thinned trees those unthinned which were bearing a far heavier weight of fruit, suffered severely, many large branches being broken. This alone would have an effect on future yield apart from any possible effect of the strain on the unthinned trees of carrying a breakdown crop and the risk of infection by the Silver Leaf fungus through the broken branches.

As to the cost of thinning, allowing for the extra care necessary in picking experimental trees, and the reduction in the cost of picking, handling and grading a smaller crop, and of shoring up trees, the cost of thinning worked out at about 6d. a tree, or 1½d. per half-sieve of fruit produced. There is often, of course, a real difficulty in finding the necessary labour for thinning, but it must be remembered that if you thin you are going to have a good deal less to do at picking time when you may be much more pressed for labour and time.

In our experience, plum thinning can safely be started early in June. As regards distance apart, much must depend on the condition of the trees, but we are inclining to the belief that wider spacing than is usually practised may be desirable, and experiments are being made to ascertain the optimum distance.

The first of these where 1 inch spacing was tried against 2 inches has already been carried out. Though 2 inch thinning produced a larger plum and eliminated more low grade fruit, there was in this instance little difference in the financial return. The main points of interest in the experiment were as follows: (*a*) Thinning to 1 and 2 inches apart has been found to involve the removal of anything

* Cambridge Gage, Old Transparent Gage, Laxton's Gage, Ontario, Warwickshire Drooper, Oullin's Golden Gage, Old Greengage, Reine Claude de Bavay, Giant Prune, Bryanston Gage, Late Transparent Gage, Jefferson's Gage, Belle de Louvain, Early Laxton, Coe's Golden Drop, Victoria, Cox's Emperor, Comte d'Althan's Gage, President, Late Orange, Denniston's Superb, Golden Transparent, Monarch and Czar.

between 50 per cent. and 70 per cent. of the crop when the trees are heavily laden. (*b*) The rather low percentage of National Mark sized fruit, less than 30 per cent. produced by 2 inch spacing showed that more drastic thinning may be necessary with heavily laden trees, if a higher proportion of National Mark sized fruit is desired. (*c*) The more heavily thinned trees matured their fruit earlier, which may often prove to be valuable. (*d*) The dull muddy appearance usually associated with heavy crops appears to be correlated with size, the heavier the thinning the less there is of this type of fruit. (*e*) The economic return with both treatments was satisfactory.

In 1939 also we thinned a heavy crop of Czars to 2 inches apart with the result that most of the fruit was of National Mark size, which for the first half of the season seldom fetched less than 2s., and never at any time less than 1s. per 12 lb. chip (gross).

Grading for Quality and Size.—Whenever possible we grade all varieties of plums, both for quality and for size, using the National Mark standards where these apply. Graded plums seem to be preferred on the market and usually sell first. This is important in years of glut when fruit that sells first usually sells best. If a mechanical grader is used there is little or no extra trouble in grading to three or more sizes and if the plums are sent along a grading belt before being passed into the grading machine the blemished ones can easily be detected and thrown out. If sizing is done by hand we suggest throwing out the very small fruits and putting the rest into two sizes, say National Mark and one other.

Cold Storage of Plums.—The problem of how to market plums successfully in a glut year or in a season when varieties all seem to come in together inevitably raises the question of how far it is possible to extend the marketing season by means of cold storage.

As is well known, we do not carry out any fundamental research on fruit storage at East Malling, since that work is done at Ditton Laboratory and at the Low Temperature Research Station, Cambridge, by Drs. Kidd and West and other workers. What we do here is to apply their findings to the commercial storing of our fruit. This, of course, is done on a larger scale than when carrying out a closely controlled experiment, and consequently it is possible for us to warn the grower as to some of the practical difficulties he may encounter.

We have found, first, that there is no advantage in storing those varieties of plums which are earlier in season than Victoria.

Fruit for storing must be picked before it is mature and with the stalks on, the right stage being when it is still firm but commencing to colour. It must be graded for maturity before being put into store, and ripe fruit should never be mixed with unripe. Damaged fruit should never be stored as it may only be a source of serious Brown Rot infection. In the chamber the engines should be started two days before storing so as to get the chamber thoroughly cooled down.

The fruit should be got into store as soon as possible after being picked, the same day if at all practicable. If the weather is hot a few hours delay will greatly shorten its storage life.

If possible arrangements should be made for a gradual raising of the temperature of the fruit as it comes out of store, in order to minimize condensation. This is easy where there are two stores with a connecting internal hatch, fruit being transferred to the second store the day before it is required for market and the temperature allowed to rise gradually.

Damsons and certain plums such as Warwickshire Drooper and Greengage, tend to shrivel in store. This is especially noticeable in the top trays. Shrivelling can be lessened by placing two or three empty trays on top of the stacks.

Different varieties behave very differently in store. Some, such as damsons, bush plums and greengages, will keep several weeks ; the life of others, such as Czar, Giant Prune and Monarch, is extremely short. Again the flesh of some varieties such as Giant Prune, Monarch and Pond's Seedling is prone to suffer from internal browning, though appearing outwardly in good condition. Once out of store plums ripen up with great rapidity. Hence they should always be brought out two to three days before they are ripe.

Two Important Plum Diseases.—*Silver Leaf and Bacterial Canker.*

Silver Leaf—(*Stereum purpureum*). *Time to Prune.*—Fruitgrowers are already familiar with the fact that the Silver Leaf fungus is a " wound parasite ", gaining access to the tree through wounds that expose the " wood " tissues.

Some years ago Professor F. T. Brooks of Cambridge University carried out artificial inoculations with the Silver Leaf fungus on two series of Victoria plums at East Malling, one set of trees being infected each month throughout the year. He found from this experiment no difficulty in producing the disease by inoculation, from October to March, but from April to August infection was difficult. These results clearly indicated late spring and summer as the right time to prune to avoid infection of plum trees by Silver Leaf. But how will pruning at such a time affect the growth of the trees ?

An experiment was made here with some ninety trees of Victoria Plum divided into three series. Pruning was done in January, in early May, and in August. The trees pruned in January and August

behaved alike ; one or two buds at the tip of each cut leader made strong leading shoots, giving a somewhat open and spreading tree. In the third series, growth had already started when the trees were pruned in May, with the result that they produced a dense bristly head of shoots, growing out at right angles. The general effect of this treatment was to reduce vigour, there being more, but weaker, shoots, and the trees making less girth increment than under normal pruning treatment.

Since Silver Leaf infection can come from almost any dead wood in the neighbourhood it is desirable always to paint wounds made in plum pruning and for this purpose we use here a paint made up of 2 lb. white lead paste, 2 tablespoonfuls of paste driers, 2 tablespoonfuls of raw linseed oil, and 2 tablespoonfuls of turpentine.

Bacterial Canker.—*Winter Stem Cankers and Summer Leaf Spots.*—Bacterial canker is familiar to many growers under the name of "dieback". The bacterium gains entry through a wound into the lower layers of the bark of the stem during the autumn, probably mainly during November. Here it lives and destroys the bark, the cambium, and the wood next to the cambium. The diseased area may extend in a long narrow strip for several feet up and down the stem or it may spread round the circumference "ringing" the tree. On cutting the bark this diseased area has a brown appearance, but no further evidence of disease is visible until growth commences in the following spring. Trees completely ringed by the canker will then put out small yellowish leaves, may possibly just set fruit, and then die. Trees only partially ringed grow normally and show few leaf-symptoms, though they often produce rather more blossom than undamaged trees. As the season progresses such trees show a ridging on the stem where the healthy bark is growing alongside the dead bark. The bacteria gradually die out during the summer because conditions in the sap of the tree become unsuitable for them to live, and this is the reason why bacterial cankers do not continue to extend year after year as apple cankers do. In the autumn these trees run no more risk of infection by the bacteria than a healthy tree would, and as time goes on the cankers tend to become healed over by a callus growing inwards from the edge.

During the spring and summer conditions in the bark are unsuited to the bacteria, but they are found in the leaves producing small lesions or spots about 1/10 in. in diameter. These lesions are more or less circular, dark brown with usually a narrow pale zone round each, forming a "halo". Eventually the affected areas are killed and drop out leaving "shot holes". The bacteria are spread mainly in drops of water, and in wet seasons almost every leaf on a tree may become affected. While it is obvious that this damage to the leaf must weaken the tree to some extent, the leaf spot is serious also because it *keeps the bacteria alive on the tree until the autumn* when it can once again infect the bark, and by the time all the leaves are off, the bacteria may have established themselves in the stem of the tree.

From observations made during the past three years it seems possible that the bacteria can overwinter in or on the buds, and in view of this risk it is advisable that buds for propagating should be taken from healthy trees only and if necessary such trees could be given a regular spraying as indicated below.

Double Working as a Control for Bacterial Canker.—It has been found that the canker phase of the disease generally attacks the main stem and very seldom attacks the branches, and that while certain varieties are very susceptible, others are seldom infected. The discovery led to the idea of double working susceptible varieties over a resistant intermediate or "stem piece". Trees were built up in three parts, a rootstock of Myrobolan B, a resistant stem, and the susceptible variety Victoria, as the head. From these experiments it was found that Victoria, Pershore and Denniston's Gage are very susceptible and therefore unsuitable as intermediates, but that President, Utility, Purple Egg, Warwickshire Drooper and Myrobolan B show a high degree of resistance to bacterial canker. Stems of President and Purple Egg are to-day producing larger trees of Victoria than any of the other stems in the experiments, and so should be specially suitable. When Myrobolan B is used as a stem care must be taken to plant the trees before March, as this variety leafs out early and is liable to suffer a severe check if planted later.

Time to Prune.—A series of experiments has shown that the bacteria infect the trees through wounds most easily during the autumn and winter months, and that it is almost impossible to obtain infections during the period of active growth. In the experiments with intermediate stem-pieces described above we tried the effect on the growth of the trees of pruning in May and September respectively. The results confirmed the earlier observations and have led us to make the general recommendation to prune all leader shoots, broken branches and feather shoots of plum during the growing seasons, preferably during the months of May and June. As stated above, these months are suitable also from the point of view of avoiding Silver Leaf infection. Care should be taken to avoid causing wounds at other times, as for instance by the careless use of tractors.

Spraying.—Our work on the control of bacterial canker by spraying has been in two directions :

Spraying for the Control of Stem Cankers.—In previous experiments with sweet cherries, Bordeaux mixture to the formula 10 lb. copper sulphate, 15 lb. hydrated lime, 100 gallons water (10-15-100).

applied in autumn, had given very good results in reducing the numbers of cankers. Accordingly we tried the same treatment for some trees of Victoria plum double-worked over different intermediates on to Myrobolan B. Few cankers occurred so no reliable conclusion can be drawn from the experiment, but a slight reduction in the number of cankers was effected by spraying with Bordeaux (10-15-100) about the third week in October. A further trial of autumn sprays for the control of canker is planned.

Spraying for the Control of Leaf Spots.—This seems to be mainly a problem of correct timing of spray application and of finding the strength at which it can be used with safety on plum foliage. The spray treatments compared in 1939 were: (1) Bordeaux mixture at 6-9-100 with a spreader, applied at bud-burst, at 4-6-100, applied three weeks after petal-fall, and at 4-6-100 with cotton-seed oil (0·75 per cent.), applied six weeks after petal-fall; (2) Bordeaux at 4-6-100, applied once, at petal-fall; and (3) Bordeaux at 4-6-100, applied at petal-fall and again three weeks later. There were in addition, unsprayed control trees.

So far, the petal-fall application seems to have had little effect on leaf-spot; this period is probably too early. The later ones, however, have been definitely beneficial in reducing infection not only of leaf-spot but also of plum rust, *Puccinia Pruni-spinosae*. The value of the application at bud-burst is not yet determined. At 4-6-100, Bordeaux caused fairly severe spotting of the foliage, but the inclusion of cotton-seed oil obviated this spray damage. It is questionable whether the expense of several sprays or the extra expense of adding the oil is worth while on the cheaper plums, but it should prove economic on higher grade plums such as gages. Problems for the future are to test the toxicity and safety of lower strength Bordeaux, to test other bactericides, and to find the minimum spray schedule necessary for good control. This last problem must necessarily be closely linked with correct timing of spray application. Attention will be paid to the prevention of fruit marking by deposit from the later sprays.

Summary.—A brief account of the main lines of research carried out at East Malling Research Station during the last 25 years on the subject of commercial plum growing. Recommendations are made for choosing rootstocks and for framework grafting established trees. Reference is made to the most recent findings on thinning, grading, and storing of plums, and to investigations into Silver Leaf and Bacterial Canker.

STUDIES IN NURSERY TECHNIQUE

THE PRODUCTION OF DOUBLE-WORKED PEAR TREES

By R. J. GARNER and D. H. HAMMOND

CERTAIN pear varieties have often proved unsatisfactory when single-worked upon some quince rootstocks. Double-working has been employed to produce trees of these varieties upon quince. Amongst the varieties for which double-working is advocated (Argles, 1937), is Williams' Bon Chrétien (syn. Bartlett). Increasing interest is being shown in this dessert variety and as it has so often proved unreliable direct upon quince, and difficult to grow for good quality fruit when worked upon pear rootstocks, it was thought desirable to investigate the technique of double-working in order, if possible, to encourage the double-working of this and other varieties of similar behaviour.

The usual method of double-working pears is to work a quince rootstock with a variety known to grow well upon it, and, one year later, to graft the desired variety a few inches above the first union. Thus the maiden double-worked tree requires three years for its production from the time of planting the rootstock, compared with two for the single-worked tree. It has been suggested (Bailey, 1911) that double-working may be carried out satisfactorily in one operation but it appears that re-working one year later has remained the normal nursery practice.

Double-worked trees cost more to produce than single-worked. This increased cost is due mainly to the extra year in the nursery and the additional manipulations entailed tend to decrease the number of trees produced.

It was thought that the production of double-worked trees might be hastened and cheapened by the employment of methods differing from those most commonly used in nurseries, and trials were begun in the Station's nurseries in order to test the practicability of such methods. From 1920 onwards experience had been gained in the double-working of both apples and pears for experimental purposes (Grubb, 1939). Some of the trees were raised by budded scions and others by double-grafting in one operation.

Trials at East Malling.—In the winter of 1937-8 one row each of re-selected clones of East Malling Quince A and Quince C were planted next each other in the nursery ; each row contained over 600 rootstocks. These grew normally during 1938 and were grafted in March, 1939, in accordance with the following scheme.

Treatment A.—Double-worked in one operation in March, 1939, the head of the tree to be formed at " knee " height in 1940.

Treatment B.—Worked with an intermediate in March, 1939, and re-worked at " knee " height in March, 1940, the head to be formed from the scion in 1940.

Treatment C.—Worked with an intermediate in March, 1939, and re-worked a few inches above the first union in March, 1940, the head to be formed in 1941.

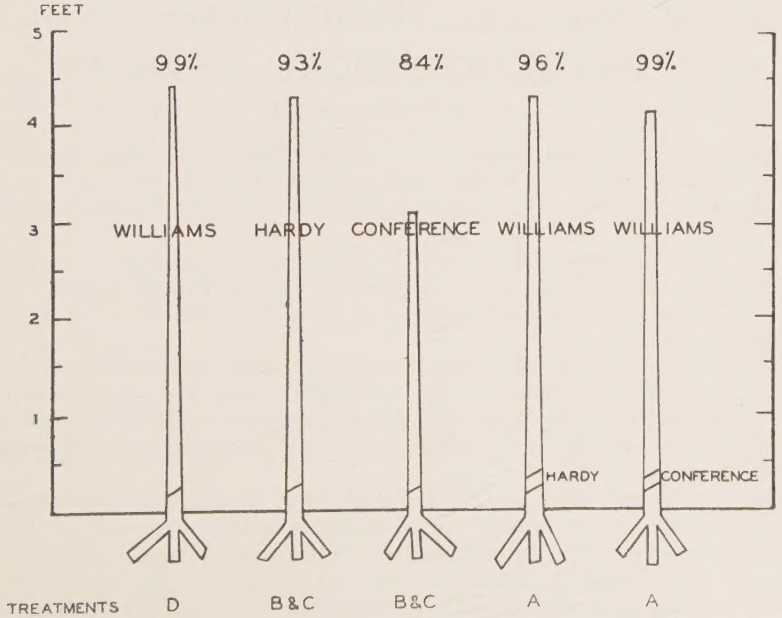
Treatment D (*Control*).—The second scion worked direct on to quince in March, 1939, the head to be formed at " knee " height in 1940.

The treatments were repeated four times on each rootstock and for each scion variety, and were arranged so that any possible differences due to position could be observed and discounted.

Two varieties, Beurré Hardy and Conference, were selected for use as intermediates, for the following reasons. Beurré Hardy unites well with quince ; it is commonly used as an intermediate in Europe and has been reported as making excellent growth on quince from other parts of the world (Argles, 1937). Conference is not prone to scion-rooting (Hatton and Bagenal, 1933), and this habit might prove useful should the union become buried when the tree reaches the plantation. It has been suggested (Grubb, 1939), however, that this variety may prove unsatisfactory as an intermediate because it produces variable trees when used as an intermediate for Beurré Clarigeau and Souvenir du Congrès. Williams' Bon Chrétien was the upper scion in all cases.

All the grafting was done by the staff of the Propagation Section and no exceptional precautions were taken to ensure success. Whip-and-tongue grafting was used throughout with raffia for tying, and hot red wax (Garner and Walker, 1938) for sealing. The scion-wood of the intermediates used in Treatment A was cut into 5-inch lengths in March and immediately grafted with a three-bud scion, of Williams' Bon Chrétien, sealed and placed upright in a box of peat. Two or three days later they were grafted on the quince at 3 inches above ground level. When the operation was complete the minimum length of the intermediate between the upper lip of the stock and the lower lip of the second scion was 2 inches. All the rootstocks were grafted at the same time with the intermediate varieties, or with Williams' Bon Chrétien, as required by the plan. All scions, except the intermediates in Treatment A, had three buds. There were ten combinations of stocks and scions : Williams' Bon Chrétien on Beurré Hardy (or Conference) on Quince A (or Quince C), Beurré Hardy (or Conference) on Quince A (or Quince C), and Williams' Bon Chrétien on Quince A (or Quince C).

Growth at the End of the First Season.—All the trees made good growth during 1939, no



Average height of trees one year after grafting, and percentage saleable.

combination producing less than 84 per cent. of saleable trees. For purposes of comparison a tree of 25 inches and over was considered to be " saleable ". The unions were complete and no signs of ill-health were apparent in any of the trees passed as saleable. It should, however, be noted that deterioration of trees of Williams' Bon Chrétien worked direct on quince has often been delayed until a few years after working. Sometimes single-worked trees of this variety on quince continue to make vigorous growth for many years but are always apt to break at the union.

Single-worked trees of Williams' Bon Chrétien made most growth, with Beurré Hardy a close second. Conference was much smaller at the end of the maiden year., Amongst the double-worked trees all combinations made almost equal growth ; the less vigorous growth of Conference when single-worked was not reproduced when used as an intermediate. Of the 288 trees double-worked in one operation, 281, or over 97 per cent., made saleable maiden trees.

The percentage of saleable trees produced and the growth of each stock/scion combination is shown in the diagram. As no outstanding differences between trees on Quince A and Quince C were apparent at the end of the maiden year, trees on the two rootstocks have been added together to simplify the diagram.

Summary.—The pear Williams' Bon Chrétien has proved unsatisfactory when worked directly upon certain quince rootstocks, and it should be double-worked. The cost of double-working is compared with that of single-working. Three methods of double-working are under trial to test their efficiency. The growth and number of trees produced at the end of the first season is given in a diagram. Those double-worked in one operation in March produced over 95 per cent. saleable trees by the end of the season.

References

Argles, G. K. (1937). " A Review of the literature on stock-scion incompatibility in fruit trees, with particular reference to pome and stone fruits." *Tech. Comm. imp. Bur. Fruit Prod.* **9**, 113 pp.

Bailey, L. H. (1911). *The Nursery Book*, p. 134.

Garner, R. J. and Walker, W. F. (1938). " The frameworking of fruit trees." *Occas. Paper, imp. Bur. Fruit Prod.* **5**, 14 pp.

Grubb, N. H. (1939). " The influence of intermediate stem-pieces in double-worked apple and pear trees." *Sci. Hort.*, **7**, 20.

Hatton, R. G. and Bagenal, N. B. (1933). " Scion Rooting at East Malling Research Station." *Kent Fmrs' Journ.*, **33**, 226-9.

BIOCHEMISTRY

THE STUDY OF MINERAL DEFICIENCIES AND EXCESSES BY SPECTROCHEMICAL METHODS

By S. G. THOMPSON

Recently developed methods of detecting mineral deficiencies and excesses are of direct interest to the grower since they point the way to increased crop production, and to economies in artificial manures. It is becoming increasingly clear that loss from various diseases is often due to faulty nutrition.

Recent research in many parts of the world is proving the importance of a number of elements which have hitherto been disregarded ; for example, the work of Roach suggests that deficiencies of iron, manganese and zinc cause serious trouble, and are at least as common as those of nitrogen, phosphorus and potassium.

The large and increasing number of elements which it is now necessary to study, and the minute quantities in which some of them occur, make analysis by ordinary methods quite impracticable, consequently other methods must be employed and of these spectrochemical analysis is perhaps the most promising as it is very economical in time, money and material once the expensive apparatus necessary has been installed.

Spectrochemical analysis is based on the fact that many elements, when raised to a sufficiently high temperature, emit light of " colours " characteristic of the element. If this light be passed through a prism it is separated into its constituent " colours ", as in the rainbow. This spectrum can be photographed, each colour appearing as a line on the plate ; the relative position of this line to others is fixed ; thus an examination of the photograph tells what elements are present, and the density of the lines may be used to estimate their quantities.

As the lines of many elements may be present in one photograph, or spectrogram, and as a number of spectrograms can be taken on each photographic plate, each plate can be used for estimating many elements in many samples.

It has been found that healthy plant material of the same sort collected in different places showed very similar spectra, e.g. spectra of healthy pear leaves from Kent and South Africa were closely similar. On the other hand spectra of leaves of unhealthy trees may differ widely from those of healthy trees of the same variety growing in the same plantation. This method of comparison has been used to detect faulty nutrition and the conclusions drawn have been verified by other methods. Three main types of problem have been met, (1) deficiencies of one or more elements, (2) excesses of one or more elements, (3) cases of the " lime induced chlorosis " type where the balance of several elements is abnormal.

Deficiencies.—A deficiency of manganese detected by this method in peach trees in South Africa was cured by injection at a cost of 2d. per tree and by spraying at a cost of 6d. and, as a result, some hundreds of trees which had borne no fruit for a number of years produced a full crop, worth in a normal year £2 to £5 per tree. Deficiencies of iron, manganese and copper have been detected in a similar manner in fruit trees in this country, and curative methods are being evolved.

Excesses.—Excesses of elements can also be detected, which sometimes should make possible economies in artificial manures. In view of the many qualities such as disease resistance, keeping quality, etc., desirable in a fruit tree, a careful study must be made of the quantity of each element in relation to these characters.

Lime Induced Chlorosis.—Chlorosis due to a deficiency of iron in the plant is common on heavily limed soils, especially where there is a shortage of organic matter, even though the soil contains large quantities of iron. There is a similar relation between lime and manganese. In deficiencies of this nature there may be no actual shortage of the nutrient in the soil, but owing to the effect of some other substance the plant fails to utilize one or more of the soil minerals. Such cases are quite common and the deficiency can be made good by injection of the trees, but this, of course, does not deal with the underlying problem of a faulty mineral balance in the soil.

The spectrogram given by leaves suffering from this type of deficiency is characteristic, showing excesses of some elements and deficiencies of others. Spectrochemical analysis and tests by injection have shown that such induced deficiencies of this type occur on a wider range of soils than was formerly suspected and that the influence of one mineral on the uptake of another needs further study. There are reasons for suspecting that excess phosphate also interferes with the normal uptake of iron, manganese and other elements.

The above examples give some idea of the complexity of the problem. The application of the method is limited by the fact that not all elements can be determined spectrographically. The method, however, has already yielded results of great practical value, and its field of usefulness will be enlarged when the remaining elements are determined by other methods.

Mineral nutrition is, of course, only one of the many essentials for efficient fruit production, and it is little use paying undue attention to it if growth is limited by some other cause.

Experience suggests, however, that faulty mineral nutrition is common and if growers would consult this Section through the usual channels, the workers concerned would be glad to discuss with them the advisability of applying these methods to their particular problems.

Summary.—Spectrochemical methods of analysis recently developed at East Malling are being applied to nutritional problems in commercial plantations.

Results obtained prove that both in England and overseas, deficiencies of elements such as iron, manganese and zinc which occur in minute amounts are often of as great economic importance as deficiencies of nitrogen, phosphorus and potassium.

INDEX

Analytical Methods, 56
Angular Leaf Spot, 63
Anatomical Studies of Rootstocks, 20, 23
Apple Blossom Weevil, 30
——— Canker, 33
——— capsid control, 32
——— chlorosis, 55
——— rot following scab, 60
——— root growth, 22
——— roots, anatomy, 23
——— rootstocks, 20, 22, 37
——— ———, immune from Woolly Aphis, 44, 46
——— Scab, 33, 75
——— storage, 14
——— trees in water culture, 26
——— Woolly Aphis, 30, 44, 46
Apples, acreage grown, 13, 14
———, cropping, 14
———, double-working, 21, 22
———, frame-working, 14
———, new seedlings, 21
———, returns, 14
———, varieties grown, 14
Arsenate-sulphur sprays, chemistry of, 32
Atomized sprays, 32

Bacterial Canker, 28, 33, 61, 83
Bactericides, metallic salts as, 32
Biennial Bearing, 26
Big Bud Mite control, 33
Black Currants, acreage, 15
———, Reversion in, 31
Blossom Wilt in Morello cherries, 60
Botrytis Rot of hop cones, 16, 62
Bradbourne, crops grown, 17
Branch-blister Disease, 33
Breeding, 21, 38, 44, 46
Brown Rot Diseases, 60
——— control in Morello cherries, 33

Calcium deficiency, 54
Cane Spot, 28, 68
Chafer Beetle on fruit trees, 70
Cherries, acreage grown, 15
———, chlorosis in, 55
———, cropping, 15
———, frameworking, 15
———, returns, 15
———, rootstocks for, 38, 41
———, varieties grown, 15
Chlorosis, 53, 55
Codling Moth, 32
Coral Spot Canker, 60
Cox Spot, 59
Crown Gall, 28
Crown Rot of hops, 62
Currant Leaf Spot, 61
Czar Spot, 59

Die-back of Loganberry, 59
Double-working, 21, 22, 83, 84
Downy Mildew of hops, 16, 62
Dwarf Lateral Scorch, 29

Experimental Design, 25
Experimental Farm, present acreage, 13
——— nurseries, acreage, 16
——— ———, sales from, 16

False Crinkle in strawberries, 59
Frame-working fruit trees, 14, 15, 20, 80
Frost damage, 21
Frost resistance induced by iron injection, 53
Fungicides, organic chemicals as, 32
———, sulphur sprays as, 33

Gall Mites, 31
Grapes, analyses of leaves, 55
Green Chafer beetle, 70
Grey Mould on currant leaves, 61
—— ——— of hops, 62

Hop, Botrytis rot, 16, 62
—— Canker, 62
—— Crown Rot, 62
—— Cultural Treatments, 76
—— Downy Mildew, 62
—— Entomological Investigations, 35
—— Grey Mould, 62
—— Mosaic, 35
—— Nettlehead, 35, 62
—— Red Spider, 36
—— Strig Maggot, 35
—— Verticillium Wilt, 34, 62
Hops, acreage, 16
——, cropping, 16
——, returns, 16
——, varieties grown, 16
——, varieties and cultivation trials, 34
Hydrogen ion concentration, effect on growth of bacteria, 32

Inarching, 20
Injection, 27, 51
Iron deficiency, 53

Lead arsenate residues on apples, 32
Leaf analysis, 54
Leatherjackets, 73
Light Emerald Moth, 71
Lime induced chlorosis, 55, 87
Loganberry Cane Spot, 28, 68

Manganese deficiency, 52
Manuring, 20, 22, 33, 34
Mediterranean Fruit Fly, 73
Medlar Leaf Blight, 61
Metallic salts as bactericides, 32
Meteorological Observations in 1939, 50
Mineral analysis of plant parts, 54
Mineral deficiencies and excesses, 51, 86
——— deficiency in peaches, 55

Nut Weevil, 70

Organic chemicals as fungicides and ovicides, 32
Ornamental cherries, 44
Ovicidal action, physiology of, 32
Ovicides, organic chemicals as, 32
———, petroleum oils as, 32
———, tar oils as, 32
Own roots, trees on, 37

Papery Bark, 59
Peach, chlorosis, 53
——, mineral deficiency in, 55
——, rootstocks for, 38
Pears, acreage, 14, 15
——, cropping, 15
——, double-working, 84
——, frame-working, 15, 20
——, returns, 15
——, rootstocks for, 38
——, varieties grown, 15
Petroleum oils as ovicides, 32
Phenomenal Berry, Cane Spot, 28, 68
Plant hormones, 25
Plum Bacterial Canker, 33
Plums, cold storage of, 82
——, cropping, 15
——, double-working, 83
——, frame-working, 15, 20, 80
Plums, on own roots, 79
——, pruning, 83
——, returns, 15
——, rootstocks for, 38, 79
——, thinning, 81
——, varieties grown, 15
Pruning, 20
Psychid Moth, 71
Pyrethrum, 32

Quince rootstocks for pears, 38

Raspberry Beetle, 32
——— Cane Blight, 61
——— Cane Midge, 72
——— Cane Spot, 28
——— Mosaic, 30
——— Moth, 71
———, New Seedling Varieties, 21
———, Propagation of virus-free clones 21
Red Leaf Aphis on apple, 72
Red Spider, 17, 33
Reversion in black currants, 31
Rootstock influence, 39, 42
——— and Scion Incompatibility, 20, 39, 79
Rootstocks, anatomical studies, 20, 23
———, for apples, 37, 44, 46
——— —— cherries, 38, 41
——— —— peaches, 38
——— —— pears, 38
——— —— plums, 38
——— —— walnuts, 39
Root Studies, 22, 23

Sampling technique, 25, 31
Short-Cloaked Moth, 70
Silver Leaf, 52, 60, 80, 82
Small Fruits, acreage, 15
———, clonal races of, 21
———, cropping, 15
———, returns, 15
Soil test for availability of iron, 53
Sooty Blotch, 61
Spectrographic methods of chemical analysis, 27, 56, 86
Spray damage, 13, 17, 26
Spraying programme, 17
Stem-builder intermediates, 22
St. Mark's Fly, 72
Strawberry Aphides, 25, 31, 72, 73
——— Crinkle, 29, 67
——— runners, dipping, 73
——— Tarsonemid Mite, 71
——— virus diseases, 29, 66
——— virus-free plants, 21
——— Yellow-edge, 29, 66
Sulphur sprays as fungicides, 33

Tar oils as ovicides, 32
Tortrix caterpillar on strawberry, 71

Variation in apple and pear trees, 24
Vegetative propagation, 25
Virus diseases of cultivated Rubi, 29
—— ——— — strawberry, 29, 66
Virus-free clones, propagation of, 21

Walnuts, 21
Water-cultures of apple trees, 26
Weather conditions in 1939, 48
Winter washes, omission of, 33
Wireworms, 70
Wood-boring beetles, 70
Woolly Aphis, 30, 44, 46